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Literacy scores, human capital and growth across fourteen OECD countries

INTERNATIONAL ADULT LITERACY SURVEY
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ENQUÊTE INTERNATIONALE SUR L'ALPHABÉTISATION DES ADULTES

Serge Coulombe,
Jean-François Tremblay, and
Sylvie Marchand

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International Adult Literacy Survey

Literacy scores, human capital and growth across fourteen OECD countries

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Summary

We derive synthetic time series over the 1960-1995 period on the literacy level of labour market entrants from the age structure of the 1994 International Adult Literacy Survey. This information is then used as a measure of investment in education in a panel data analysis of cross-country growth for a restricted set of 14 OECD countries.

The central result of the paper is that direct measures of human capital based on literacy scores outperform measures based on years of schooling in growth regressions. The results indicate that, overall, human capital indicators based on literacy scores have a positive and significant effect on the transitory growth path, and on the long run levels of GDP per capita and labour productivity.

The key economic policy implication that comes out of this result is that, in contrast to most previous findings, human capital accumulation matters for the long run wellbeing of developed nations.

Preface

Recent work

Krueger and Lindahl (2003) highlight the fact that estimates of the magnitude of human capital's impact on rates of productivity growth and overall economic growth are far lower than estimates of its impact on wages and other labour market outcomes observed at the individual level. They attribute this disconnect to the poor quality of the human capital measures employed in macroeconomic growth models. Analysis of data from the International Adult Literacy Survey (IALS) has already demonstrated that directly assessed literacy and numeracy skills have a significant impact on a range of social and labour market outcomes observed at the individual level impacts that come on top of those attributable to educational attainment.

This paper represents a first attempt to capitalize on the improved measurement properties of the IALS results, specifically to estimate the impact that the level and distribution of directly assessed skill have had on rates of productivity growth and overall economic growth over the period 1960-1995 for a group of fourteen highly developed OECD economies.

The results are noteworthy in two respects.

First, they confirm that using better data on actual economically productive skills increase the importance of human capital to growth close to level observed at the individual level.

Second, they suggest that raising the average literacy and numeracy skill level of the workforce, and reducing the proportion of workers at the lowest level of skill, could yield significantly higher levels of growth in GDP per capita.

This analysis will be refined and extended comparable when data from the Adult Literacy and Life Skills Surevy (ALL) become available in December, 2004.

T. Scott Murray and Yvan Clermont - editors

1. Introduction

The study of the determinants of economic growth has been one of the most important fields of research since the mid 1980s in economics.[1] This field of research has been spurred by the endogenous growth literature pioneered by the theoretical analysis of Paul Romer (1986) and Lucas (1988) and the growth-empirics approach that started with the testing of the neoclassical convergence hypothesis (Baumol, 1986, Barro, 1991, Barro and Sala-i-Martin 1992, and Mankiw, David Romer and Weil, 1992) and was fuelled by the development of comparable cross-country data on GDP, productivity and human capital indicators (Summers and Heston, 1988, and Barro and Lee, 1993, 1996). In both the endogenous growth and the growth empirics approaches, the concept of human capital, or education, has been at the centre of influential studies (Lucas, 1988, and Mankiw, Romer and Weil, 1992).

In studies of a broad set of countries including developed and less developed countries, standard measures of human capital based on educational achievement appear to have a positive and significant long run level effect on countries' GDP and a transitory positive effect on economic growth during the convergence process toward the steady state (Barro, 2001). This is the best effect a variable such as human capital can have on economic growth in a neoclassical framework since labour productivity growth in the long run is solely determined, in this model, by the growth rate of technological progress (Solow 1956).

One of the most puzzling results in the empirical literature on human capital and growth is, however, that, when the sample under study is restricted to the OECD countries, the effect of human capital or education on economic growth is not significant, sometimes null, or even negative (Islam, 1995). One good example of this is Barro's (2001) point estimate of 0.0000 for the effect of his preferred human capital indicator (male upper school) when his growth regression is restricted to the OECD sample.

One of the reasons behind this negative result might be associated with the fact that human capital is a concept that is not straightforward to measure given that it is not usually exchanged in markets like other economic goods. For this reason, human capital is usually measured in an indirect way by using educational attainments and/or enrolment rates. But such human capital indicators might not be very comparable at the cross-country level given the wide variety of educational systems around the world. In a recent contribution to the topic, de la Fuente and Doménech (2002) address the data quality issue and conclude that the growth effect of corrected (for measurement errors) average schooling indicators across 21 OECD countries is positive and significant.

In this paper, we contribute to the analysis of the relationship between human capital and growth across OECD countries by making the best use of direct measures of human capital based on literacy scores. The literacy raw data come from the 1994 International Adult Literacy Survey (IALS), which tested the skills of individuals aged between 16 and 65 and are available for fourteen OECD countries. A historical perspective on human capital accumulation is required to test the growth effects of investment in education. We use the age distribution of the test results to construct a synthetic time series, over the 1960-1995 period, of the literacy level of the young cohort entering

the labour market in each period. The relative literacy level of these cohorts is seen as an indicator of a country's investment in human capital relative to the other countries in the sample.

Our first set of results concords with the analysis of de la Fuente and Doménech (2002) since the human capital indicators based on literacy have a positive and significant effect on the long run GDP level and labour productivity, and on the growth rate in the transitory process toward steady state. In our restricted set of OECD countries, the human capital data based on literacy scores performs even better that the corrected schooling data used in de la Fuente and Doménech. Furthermore, given the detail of the available data on literacy, we are able to get two steps further in the empirical analysis of the relationship between human capital accumulation and growth. First, we find that human capital indicators based on average literacy scores per country perform better that comparable indicators based on the percentage of the population which has achieved top scores. This result suggests that productivity is mostly influenced by the effect of skill and human capital accumulation on the general labour force, rather than their effect on highly specialized employment only. Second, all of our results by gender indicate that the growth effects of human capital indicators based on female literacy outperform the effects measured from indicators based on male literacy. We get this insightful result even when controlling for fertility and relative female/male labour market participation rate.

A broad overview of the evolution of empirical research in human capital and growth is presented in the next section. Since our empirical analysis extends to the relative role of female and male education in growth regressions, in this section also covers the recent literature regarding the educational gender gap effect in development economics. The data are presented in section 3 and the empirical methodology in section 4. The empirical results are presented and analysed in section 5. We conclude with a discussion of the limitations of our analysis and suggest directions for further research.

2. Human Capital in Growth Regressions: an Overview

2.1 Introduction

According to the early neoclassical model of Robert Solow (1956), economic growth was driven by the improvement of productivity *via* technological advance determined outside the model (exogenous). Although appealing, Solow's model could not be tested due to the lack of reliable data. Hence, growth issues had to wait until the late 1980s to be revived by the availability of internationally comparable data on income and price levels (Summers and Heston, 1988), and by the rise of another approach to the study of economic growth – the endogenous growth models - pioneered by Romer (1986) and Lucas (1988), where the long run growth rate of productivity emerged endogenously from the model variables. Yet, empirical studies conducted through the 1990s to understand wealth differences between countries appeared to be best supported, from a qualitative point of view, by neoclassical models as synthesized in the work of Barro and Sala-i-Martin (1995). However, the basic Solow model had to be refined in order to be able to explain quantitative cross-country differences in living standards. Most importantly, the concept of capital had to be extended to account for *human* capital (Mankiw, Romer and Weil, 1992).

A pioneering work in the field of growth empirics is that of Baumol (1986) who used data on a group of countries belonging to Maddison's (1982) sample, and who appeared to confirm absolute convergence across countries. However, because countries included in the sample belonged to a group of countries that has been able to achieve a high level of development by the end of the study period, definitive conclusions could not be put forward.

The international data set of Summers and Heston (1988) provided a larger sample of countries, including poor as well as rich countries. This allowed macroeconomists such as Romer (1989) to further test and conclude that absolute convergence did not hold over a larger and heterogeneous sample of countries. More precisely, Romer found that there was no significant correlation between initial income levels and subsequent growth rates.

One important avenue of research that developed out of Baumol's and Romer's empirical findings is that of conditional convergence, in the more general context of growth empirics. In their influential paper, Mankiw, Romer and Weil (1992) (henceforth MRW) modified the early neoclassical Solow model to allow for the accumulation of human capital. Cross-country regressions led them to conclude that, instead of reaching a common steady state, each country reached its own due to differences in rates of investment, rates of population growth and in stocks of human capital that all condition a country's steady state. Since the work of MRW, the concept of conditional convergence has been many times confirmed by cross-country and panel data analysis. Growth empirics have incorporated many improvements to allow for better and more reliable testing of growth theory and has evolved to the point where it is a discipline in its own right. The remaining sections of this review focus, therefore on growth empirics analysis that control for human capital indicators.

2.2 On Conditional Convergence: Mankiw, Romer and Weil's (1992) Cross-Country Estimation

MRW's work aimed at verifying the ability of the Solow growth model to "explain international variation in standards of living." They assumed a Cobb-Douglas production function with constant returns to scale and decreasing returns to capital, augmented with the exogenous level of technological progress and stock of human capital. The principal assumptions of their model included country specific constant rates (steady state) of investment in human and physical capital. Both types of capital share a common and constant rate of depreciation. All countries share the same rate of growth of technological progress, but differ in their respective growth rate of the labour force and the starting level of technical efficiency. In other words, the cross-country differences in the steady states of income per capita emerge because of differences in the accumulation of human and physical capital, and in the growth rate of population. Hence, each country will converge to its own steady state instead of reaching a common one.

This version of the Solow model, augmented with human capital, predicts that income per capita will evolve according to:

$$\ln y(t_1) = \lambda' \beta_1 \ln s_k + \lambda' \beta_2 \ln s_h + \lambda' \beta_3 \ln\left[n+g+\delta\right] + e^{-\lambda t} \ln y(t_0)$$
$$+ \lambda' \ln A(0) + g\left(t_1 - e^{-\lambda t} t_0\right)$$

where $y(t_1)$ and $y(t_0)$ are respectively the current and initial levels of income per capita; $A(0)$ is the unobservable initial level of technology; n, g and δ are respectively the steady state growth rate of population and technological progress, and the depreciation rate of capital; s_k and s_h are respectively the fraction of income invested in physical and human capital; $\lambda' = (1 - e^{-\lambda t})$ where $\lambda = (n + g + \delta)(1 - \alpha - \eta)$ is the speed of convergence linearized around the steady state; $\beta_1 = \alpha/(1 - \alpha - \eta)$, $\beta_2 = \eta/(1 - \alpha - \eta)$ and $\beta_3 = (\alpha + \eta)/(1 - \alpha - \eta)$, where α and η represent respectively physical and human capital's share in income.

MRW also postulated that g, the rate of technological progress, is the same for all countries and that the initial level of technology $A(0)$ is a constant that varies randomly across countries. In practice, MRW included the level of technology in the disturbance term of the regression that they postulate independent[2] of all other explanatory variables. Their regression function can be written as follows:

$$\ln y(t_1) - \ln y(t_0) = \lambda' \beta_1 \ln s_k + \lambda' \beta_2 \ln s_h - \lambda' \beta_3 \ln\left[n+g+\delta\right] - \lambda' \ln y(t_0) + \varepsilon,$$

where ε includes all country-specific disturbances. But $A(0)$ is likely to be correlated with the initial level of income per capita and the other explanatory variables. If this is the case, OLS and weighted OLS are biased and inconsistent. That is, imposing a regression function with the same parameter values for all countries[3] and an initial level of technology correlated with the initial level of income per capita and the explanatory variables $-s_k$, s_h, n – will result in a set of biased and inconsistent coefficients (Islam, 1995)

MRW implemented their model for the period between 1960 and 1985 and carried out single cross-country regressions (t_0 = 1960 and t_1 = 1985) for three samples of countries: the NONOIL sample included 98 countries for which data were available, except for countries where the oil industry is dominant; the INTER sample excluded poor countries and countries whose data received a "D" grade by Summers and Heston; it included 75 countries; finally, the OECD sample consisted in 22 countries with population greater than a million. MRW considered investment in secondary education as a proxy for human capital accumulation. Specifically, their variable

SCHOOL was computed as the percentage of the working age population in secondary school, thus ignoring higher education, arguing that if this variable is proportional to s_h, then the factor of proportionality will only affect the constant term. The s_k variable is measured as the average output share of investment over the period, and the growth rate of population, n, is also the average value observed for the 1960-1985 period.

Despite the econometric problems noted above, MRW conclude that overall, their results strongly support the augmented Solow model. Specifically, their human capital variable enters significantly in the three country samples, and adding human capital improves the overall fit of each of the three regressions. It also has the effect of reducing the importance of the physical capital investment coefficient that becomes insignificant in the OECD sample regression. Their estimation of the α and η – the elasticities of physical and human capital to output – are around 0.33 and highly significant for the NONOIL and INTER samples, but less so for OECD countries alone.

These results lead them to state that differences in population growth and investments in physical and human capital should explain about 80 percent of the cross-country differences in income per capita. Yet, as we will see below, their methodology and results were not without shortcomings, which unfortunately casts shadow on their conclusions.

2.3 Towards Panel Estimation: Islam (1995)

After MRW's apparent success in explaining changes in income per capita in terms of accumulation in human capital, many researchers turned their efforts to panel data analysis. The main reason for this change was to rule out the assumption imposing an identical production function for all countries as this gave rise to the omitted variable bias cited above. Islam (1995) implemented a panel data formulation of the human capital augmented Solow production function. Instead of a single cross-country estimation, he used the data covering the same 1960-1985 period and split it into five sub-periods to benefit from five data points for each country. Moreover, Islam allowed for country-specific level (fixed) effects to correct for the omitted variable bias. The restricted form of the regression equation is:

$$\begin{aligned}\ln y(t_1) - \ln y(t_0) = {} & \lambda' \beta_1 \ln s_k + \lambda' \beta_2 \ln h^* - \lambda' \beta_3 \ln[n+g+\delta] - \lambda' \ln y(t_0) \\ & + \lambda' \ln A(0) + g(t_1 - e^{-\lambda t} t_0) + \varepsilon\end{aligned}$$

In Islam's formulation, the rate of accumulation of human capital, s_k, is replaced by h^*, the steady state level, or stock, of human capital. Therefore, the beta coefficients are modified as follow: $\beta_1 = \beta_3 = \alpha/(1-\alpha)$ and $\beta_2 = \eta/(1-\alpha)$.

As a proxy for the steady state level of human capital, Islam (1995) used Barro and Lee's (1993) HUMAN variable which provides information about the average schooling years, including primary, secondary and higher levels, in the total population over 25 years of age. Countries were divided in the same three NONOIL, INTER and OECD samples. Results from Islam's estimations allowing for country effects implied values of the annual speed of conditional convergence λ (OECD: 0.0913) that are higher than those obtained by MRW (OECD: 0.0203). Moreover, the estimated values of the elasticities of output with respect to physical and human capital, α and η, for the three country samples (α = 0.5224, 0.4947, 0.2074; η = -0.20, -0.007, -0.045) are lower than those obtained by MRW without fixed effects (η = 0.69, 0.70, 0.28; η = 0.66, 0.73, 0.76), but otherwise similar to those obtained with panel estimation excluding the human capital variable. This is not surprising because the coefficient of HUMAN is not significant for the INTER and OECD samples and has the wrong sign for all samples. As Islam notes in his discussion: "*…such "anomalous" results…are not new. Whenever researchers have attempted to incorporate the temporal dimension of human capital variables into growth regressions, outcomes of either statistical insignificance or negative sign have surfaced.*"[4]

Obviously, although correcting for the omitted variable bias has an indisputable value, what comes out of these results is that some econometric and data problems still remain. Of these, we note the fact that the growth rates and, and the speed of convergence, were still considered the same for all countries. This aspect was examined by Lee, Pesaran and Smith (1998) in a paper in which they point out that panel estimations should also allow for heterogeneity in the growth rates of technology and population (and therefore in the speed of convergence) as well as for starting levels of technology (intercepts). However, as concluded in their own paper and in the reply of Islam (1998), allowing and testing for such heterogeneity in countries' steady state growth rate involves difficulties that are not easily circumvented. For example, Islam notes in his *Reply* that the data available provides information on the *actual* growth rates whereas what would be required are the steady state growth rates.

Another potential problem to note in panel estimation is that the explanatory variables might be serially correlated.[5] This results in serial correlation problems in the disturbance and so the average effects evaluated are inconsistent. As noted in Temple (1999), the consequence of not correcting for serial correlation is that the estimated speed of convergence will be biased upwards, which might be the case in Islam (1995). This problem has been highlighted and corrected for in many panel data analysis such as Coulombe and Day (1996), de la Fuente (1998), and Coulombe (2000). However, the comparative analysis of Coulombe (2000, and 2003) indicates that serial correlation in growth regressions is a serious problem only when annual data are used in panel estimation. No significant serial correlation is detected when information is pooled in periods of five or ten years.

2.4 Refining the Methods: Barro (1997)

Using the Barro and Lee (1996) human capital data set – a refined version of Barro and Lee (1993) – which provides estimates of school attainment, Barro (1997) carried out panel estimations for 100 countries over five and ten year periods between 1960 and 1990. His estimation method includes three equations where the dependent variables are the growth rates of real GDP per capita (henceforth GDP) for 1965-75, 1975-85, and 1985-90. The explanatory variables are the lagged GDP and male schooling[6] that refer to 1965, 1975, and 1985; life expectancy at birth for 1960-64, 1970-74, and 1980-84; the interaction variable log(GDP)*male schooling is the product of log(GDP) (expressed as a deviation from the sample mean) and the male upper-level schooling variable (also expressed as a deviation from the sample mean); a rule-of-law index that applies to the early 1980s; a terms of trade variable taken as the growth rate over each period of the ratio of export to import prices; the inflation rate computed as the growth rate over each period of a consumer price index or as the GDP deflator. The other variables, measured as averages over each period, are the log of the total fertility rate, the ratio of government consumption to GDP (exclusive of defence and education), and the democracy index.

In addressing the endogeneity problem that arises when many determinants of economic growth are considered in the estimation, Barro (1997) uses a three-stage least squares technique to solve for a model with three simultaneous equations. This method relies on the use of instrumental variables where each equation includes a different set of instrumental variables. As a result, the errors from the growth rate equations should not be correlated across periods, as was the case for Islam (1995).[7]

Considering only the results related to human capital, Barro found that the years of schooling at the secondary and higher levels for males aged 25 and over had a significantly positive effect on growth for countries taken altogether. Female education appeared to have no significant effect on growth at any level when fertility is entered as an explanatory variable. He estimated that for males 25 and over, an extra year of higher level schooling raises the growth rate *on impact* by 1.2 percent per year. The life expectancy at birth also appears to have a significant impact on growth and is interpreted to proxy for the quality of the available human capital. However - and this is the point of interest for the purpose of the present research – based on growth projections obtained

from his regressions results, Barro writes (somehow speculatively) that when considering OECD countries only, increases in educational spending - as well as in infrastructure investment or research subsidies - did not provide the expected evidence of an effect on the transitory growth rate and on the long run GDP level of the economy. He then concludes in saying that "*a 2 percent per capita growth rate seems to be about as good as it gets in the long run for a country that is already rich*".

2.5 A Bird's Eye View of the 1997 – 2003 Literature

This period has been enriched by many more studies that aimed at estimating the effect of human capital on growth. In particular, many studies have focused on the effect of human capital at the intranational level because this circumvents most of the data heterogeneity problems encountered when working at the international level. Results along this line are reported below. But before doing so, it is relevant to note the apparent confusion found in the literature about the actual and the steady state growth rates of an economy. While working in a neoclassical context, some authors have reported results on the relationship between the initial level (or the accumulation) of schooling and the *long run* growth rate without referring to any different method but the neoclassical analysis framework. It is difficult to conceive how this is possible as the steady state growth rate of an economy is determined exogenously in this model.

Mauro (2000) studies the effect of human capital accumulation on the development of Italian regions for the past 30 years. When testing for different models, including those of Islam (1995) and Barro (1997), and controlling for the unemployment rates as well as accumulated job experience - the rationale for including unemployment is that it might reduce the productivity of those who cannot acquire job experience and use it to become more efficient - Mauro specifically reports a positive and significant relationship between schooling investment and *long run growth*.

Also in a paper published in 2000, Bils and Klenow develop a model to assess the causality between schooling and growth. Specifically, their model is built on finite-lived individuals where the growth rate appears to be enhanced not only by one's actual accumulated schooling years, but also by its elders' accumulated human capital that appears to potentialize the imprints of the young's human capital on the growth rate of the economy. Based on a Mincerian wage equation, however they evaluate that schooling only explains less that one-third of the relationship found by many economists between the level of schooling and the growth rate of the economy.

At this point the methods used for evaluating the impact of education accumulation on growth for OECD countries did not allow one to draw robust conclusions. Thus, after correcting for fixed effects with panel data methods, and for the endogeneity problem with the use of instrumental variables, attention was turned to the nature and quality of the data used as proxies for education. As education systems vary among countries, it made sense to try and normalize the data sets used in the estimations in order to take quality into account and also to minimize measurement errors related to data anomalies.

As Hanushek and Kimko (2000) observe, focussing only on the quantity of schooling to proxy for human capital appears to be too restrictive. In search of an better proxy, they assess a nation's labour force quality through scores obtained from students participating in international assessment of science and mathematics.[8] Starting from these test scores, they are able to construct a unique (normalized) labour force quality measure for 31 countries covering the 1960-1990 period. More explicitly, they computed a country's labour force quality measure as the weighted average over all harmonized test scores where each country's weight is calculated as the normalized inverse of its standard error. They then perform a single cross-country regression for the 31 countries over the 1960-1990 period. They regress the annual average growth rate on the initial (1960) per capita income, the quantity of schooling, the average rate of population growth, the quality of labour force and a constant. Their estimation reveals a negative and significant coefficient on the initial per capita income variable; a positive but insignificant coefficient on the quantity of schooling variable; a positive and highly significant coefficient on the labour force quality variable; and a

negative but insignificant coefficient on the rate of population growth. After testing for causality, they sum up in writing that there is a significant and positive causal relationship between the quality of labour force (in other words better productivity) and the growth rate of the economy. They also specified that although the differences between countries are related to the differences in the quality of schooling, their results do not allow them to state that this relation necessarily extends to a country's resources devoted to education. Despite these interesting findings, Hanushek and Kimko do not appear to be concerned by the inclusion of both the quantity and quality of schooling on the right hand side of the same regression equation. It is possible that these variables are correlated: where there is poor education quality, the quantity of schooling is also likely to be low as there is little incentive to remain a student given the poor envisaged future rewards. Perhaps what their results reveal is that schooling quality acts as such a better proxy for the contribution of education to growth that it eclipses the impact of the quantity of schooling. Although they report a R^2 as high as 0.73, there are no accompanying robustness tests to allow further analysis of their results.

Another study reporting the use of direct measures of schooling quality is that of Barro (2001). Data from the same source as Hanushek and Kimko (2000) are used to construct a single measure of test scores for each country, whether in science, mathematics, reading or overall. This single cross-section schooling quality data is then incorporated in the panel regression described above for Barro (1997), where the schooling quality data differs for each cross-country unit but remains the same for all the five or ten year sub-periods. The regression equation is defined by the real per capita economic growth rate as the dependent variable. The independent variables are those cited in Barro (1997). Barro's results suggest that the quality of education is much more important than the quantity as measured by average secondary and university levels of attainment. As for Hanushek and Kimko's results, Barro finds that the coefficient on the quantity of schooling variable is positive but insignificant, while that of the quality of schooling variable has a strong and significant predictive power. The paper provides neither coefficients for other variables nor any information related to tests of robustness that would allow one to guage the quality of the results.

A natural next step in growth empirics has been to turn attention towards the statistical properties of the schooling data sets used in panel estimation methods. In an important paper published in 2000 (and subsequently revised in 2002) de la Fuente and Doménech settled the importance, for OECD countries of correcting for inconsistencies and breaks in the time series attributable to changes in the measurement methods and in criteria used in classification. They studied the performance of previously existing data sets and also constructed what they consider an improved time series on schooling attainment levels. After so correcting for measurement errors, they evaluated a positive and significant relationship between the quality of the data set and the size and significance of the growth regression coefficients on the human capital variables used. In terms of performance, they concluded that their data sets were the most reliable, followed by Cohen and Soto's (2001). Finally, using extrapolated estimates of the corrected values and an extension of the classical errors-in-variables model, they evaluated that the "true" elasticity of output with respect to average years of schooling is very likely to be above 0.50.

In a study of absolute convergence across Canadian provinces, Coulombe and Tremblay (2001) use an open-economy model *à la* Barro, Mankiw, and Sala-I-Martin (1995) in which perfect capital mobility is assumed for the financing of physical capital. However, the accumulation of human capital cannot be financed abroad because domestic residents cannot use human capital or raw labor as collateral. They found that the accumulation of physical capital across Canadian provinces in the 1951 - 1996 period is driven by the accumulation process of human capital and also that the share of their human capital variable in output is around 0.5. Moreover, their results suggest that the dynamics of human capital accumulation dictates[9] the evolution of physical capital, per capita income and output, and that these key macroeconomic observables all converge at the speed of convergence of human capital.

Coulombe (2000, 2003) also studied the role of urbanization[10] in a conditional convergence context for the Canadian provinces. Extending the model developed in Coulombe and Tremblay (2001) for the open economy and imperfect human capital mobility, Coulombe uses data on the relative rates of urbanization across provinces[11] to explain the relative long run provincial steady state levels of the human capital indicator, and of nominal per capita income. The results from these studies suggest that provinces have converged at an average speed of 5 percent a year, and that the differences between the respective provincial steady states appear not to be nominal but real. Another important conclusion from these studies is that human capital alone cannot account for the observed regional disparities in the macroeconomic observables. A relatively higher degree of urbanization seems to be concurrently necessary to bring about higher long run growth.

Another interesting paper is that by Bassanini and Scarpeta (2001). Using de la Fuente and Doménech's (2000) data set and a new pooled mean group – consistent – estimator (PMG), they conducted panel data estimations for 21 OECD countries. Unlike the other panel estimations reported above the PMG is said to allow for the speed of convergence and short term dynamics and variances to vary across countries. In practice, instead of taking five or ten year intervals, they use annual data for the variables included in their regressions. However, some of the schooling data had to be extrapolated since it was only available at 5-year intervals in particular sub-samples. They conclude that they observe a "positive and significant impact of human capital accumulation" on the countries' growth paths. More precisely, they estimate that adding one more year of education has the effect of raising output per capita by about 6 percent, which they claim to be in accord with evidence from micro data. On the other hand, their estimation of the speed of convergence (around 15 percent per year) is higher than the 2-5 percent estimated by other studies based on neoclassical human capital augmented models. As already stated in previous studies and mentioned above (Coulombe and Day, 1996; de la Fuente, 1998) such high speeds of convergence are to be regarded as manifestations of business cycle short term fluctuations that arise when using annual data in panel estimations, particularly when allowing for different speeds of convergence across countries. Although the PMG approach is interesting, one should be cautious in interpreting the results of growth regressions in which the estimated speeds of convergence are of such magnitudes.

2.6 About gender specific human capital effects

The literature survey above concentrated on human capital effects on growth for a population as a whole. But a quick thought about developing countries reminds us that for many societies, education is still mainly a man's privilege. As reported by Dollar and Gatti (1999): "*In the poorest quartile of countries in 1990, only 5 percent of adult women had any secondary education, one-half of the level for men. In the richest quartile, on the other hand, 51 percent of adult women had at least some secondary education, 88 percent of the level for men.*" Why is there so little investment in girls' education in many countries remains an important question. Dollar and Gatti (1999) provide some insight. From their panel estimations, they identify religious preferences, regional factors and civil freedom as strong factors that hinder investment in girls' education. Another aspect to take into account is the fact that while women in a society might be highly educated; this is unlikely to contribute to growth if women do not have the possibility to earn income from their expertise. As Barro (2001) reports : "*One possible explanation for the weak role of female upper-level schooling in the growth panel is that many countries follow discriminatory practices that prevent the efficient exploitation of well-educated females in the formal labour market.*"

Another interesting facet to tackle in the relationship between education and growth is the impact of education on growth as the levels of income and/or education increase. Dollar and Gatti (1999) report that the relationship between income and female educational attainment is a convex function when moving from an extremely poor to a poor society. In other words, women's education has no or little effect in an extremely poor society. Only when the level of income attains a *lower-middle* income level does women's education translate into a rapid relative improvement as the society moves towards a more economically developed stage. The possibility of such a non-linear

behaviour should also be kept in mind when studying OECD countries, which remain our chosen sample for the study of education and growth.

Although gender specific effects have been studied using microeconomic data since the 1970's, the corresponding macroeconomic literature on the subject starts with Benavot (1989) who first noted the absence of empirical study on the gender specific effects of education on growth. As cited above, Barro (1997, 2001) reports that women's education appears to have no significant effect on growth at any level, which led him to formulate his hypothesis for the weak role of women's education in growth. But in Barro and Lee's (1994) previous and much cited study, the author's concluded that while male education enhances growth, women's education appears to have a negative effect on growth. Barro and Lee interpret these results in terms of a measure of backwardness and a potential for higher growth. To fix ideas, Barro and Lee's (1994) estimation of the effect of male and female education on growth uses the "seemingly unrelated regression equations (SUR)" technique. They regress growth on initial levels of stocks of physical and human capital (men and women simultaneously) and a set of variables that reflect the current political context like the black market premium, life expectancy, the number of revolutions per year and the ratio of government consumption and investment to GDP. The data used are that of Barro and Lee's (1993) average schooling years cross-country data for two ten year intervals (1965-1975 and 1975 and 1985).[12]

Barro and Lee's 1994 results run against the microeconomic evidence according to which women's education lowers fertility rates (Cain and Weininger, 1973; Blau, 1986) and increases life expectancy (Blau, 1986) Yet, when Barro – in a later 2001 study - holds the fertility rate constant, he finds that the coefficient on the female primary education variable is insignificant. But when fertility is not held constant, this coefficient becomes positive and significant, suggesting that women's primary education enhances economic growth via a reduction of the fertility rate. Moreover, another such micro study (Psacharopoulos, 1994) even reports that women's rate of return to education was positive and slightly higher than men's. Needless to say that Barro and Lee's (1994) results raised interest, and that their methods were closely examined. Two of the studies to scrutinize that perplexing result and propose explanations are that of Stokey (1994) and Lorgelly and Owen (1999). Stokey reports that Barro and Lee's women's education variable becomes insignificant when adding dummy variables for geographic location of the four Asian Tiger countries (Hong Kong, Korea, Singapore and Taiwan) and so suggests that the women's education variable appears to act as a dummy for groups (countries, ethnic groups, etc) that provide different education schemes for men and women.

These results are confirmed by Lorgelly and Owen (1999) who also find that the four Asian Tigers exert an influence such that it induces the women's education variable to become negative. The interpretation given to this is that Barro and Lee (1994) obtain these results because of the weight exerted by the low educational attainment of women in the high growth regions of Hong Kong, Korea, Singapore and Taiwan. Furthermore, Lorgelly and Owen (1999) note that the backwardness argument proposed by Barro and Lee (1994) is not convincing because the initial period income per capita is included in the estimation equation and should therefore account for the convergence process. In addition, in their in-depth analysis of the Barro-Lee model, Lorgelly and Owen (1999) find that the significance of the *male* education variable is affected by the four Tigers data. They also suggest that these volatile results are affected by a high degree of multicollinearity found between male and female education variables.[13] More generally, Lorgelly and Owen note Barro and Lee's failure to apply standard diagnostic tests for robustness. These criticisms apply as well to Perotti (1996) who also obtains a negative sign on women's education for regressions carried out using the Barro-Lee cross-country estimation technique. Perotti goes as far as providing the same backwardness explanation as Barro and Lee to justify his results.

In contrast, the literature also provides us with studies that have found a positive effect of women's education on growth. Although not without shortcomings of their own, these studies happen to obtain results in accord with micro data and the more general understanding of the

benefits of education on growth. See for example Benavot (1989), Schultz (1995), Hill and King (1995), Caselli *et al.* (1996), Birdsall *et al.* (1997), Forbes (2000), Dollar and Gatti (1999), Klasen (1999, 2002) and Knowles *et al.* (2002) . These studies use panel estimation techniques, typically with five year intervals, and aim at measuring long run effects on growth, productivity or output levels. They also estimate different equations for males and female to avoid the multicollinearity problem. As concluded by Lorgelly (2000), panel estimations that include period averages of their education measures - instead of measures in the base period – obtain a positive and significant coefficient on the women's education variable. Lorgelly also deplores the lack of formal theoretical background between education and growth and suggests that it might lead to regression results that are difficult to interpret and might even be misinterpreted in some cases. Never better served than by oneself, Knowles, Lorgelly and Owen (2002) develop an extension of Solow's human capital augmented model where they treat male and female human capital separately. Their model suggests that the narrowing of the educational gender gap contributes to increasing the level of GDP per capita in the steady state.

Despite Lorgelly's claim of the lack of theoretical models, Galor and Weil (1996) and Lagerlöf (1999) had already developed models that link fertility to growth respectively through the gender wage gap, and the gender educational gap. They both make use of an overlapping generations model in which there are positive feedback loops involving relative women's wages, fertility and growth of the capital/labour ratio in the case of Galor and Weil; or involving the educational gender gap, fertility and the growth of investments in children's education in the case of Lagerlöf. These feedback effects have the potential to drive the system into different meta-stable steady states that depend on the actions taken (or not taken) to guide the dynamic – economic - system whether on an accelerated growth path, or in a poverty trap. Both Galor and Weil, and Lagerlöf's theoretical models lead to the conclusion that an increasing gender gap in education or wages is detrimental to growth. While these conclusions are in accord with the empirical results that find a positive effect of increased women education on growth, they conversely further isolate Barro (1997) who sustains that higher levels of education for women has no effect on growth.

While thinking about the empirical setting to use when testing these two theoretical models, it is interesting to note that they both propose a double causality between fertility and educational/wage gender gaps. One should therefore remain vigilant when formulating regression specifications to avoid the potential multicollinearity problems these models involve. Moreover, the presence of a positive feedback loop linking education, fertility and growth can be understood in terms of a multiplier effect. This interesting feature is to be matched up with Psacharopoulos (1994) who reported that women's rate of return to education was positive and slightly higher than men's.

2.7 A few words about female labour force participation

The previous section briefly introduced the models of Galor and Weil (1996) and Lagerlöf (1999). We have also identified channels through which women's educational attainment can improve the level of income per capita, among which we identified a reduced fertility rate, improvements in children's health capital, and women's participation in the labour market (Dollar and Gatti, 1999 and Barro 2001). For example, Galor and Weil identify three phases of development in their model:

1. Whenever there is an increase in capital per worker, it is accompanied by an increase in women's relative wages presumably because " *capital is more complementary to women's labour input than to men's* ";
2. an increase in women's relative wages has the effect of decreasing fertility because it raises the cost of having children relative to income;
3. a decrease in fertility raises the level of capital per worker.

As for Lagerlöf :

1. With a starting educational gender gap, parents who maximize their children's household wellbeing will invest more in their son's education since their daughter will more likely marry an educated man. The reverse is less likely;
2. because the opportunity cost of having children is low for women, this association is likely to increase the fertility rate;
3. the increased fertility rate decreases investments in sons' education with the potential to drive the economy into a poverty trap.

These models have a potential for describing the evolution of developing countries. But one is justified to ask what happens if, as in many OECD countries with a high level of income per capita, the female participation rate has stabilised around that of men, while at the same time the fertility rate is at or below the replacement level and starts experiencing a slight increase? How should it affect the long run level of income per capita or the level of productivity per worker?

This is a situation quite different from what developing countries experience in the first phases of development. As the gender wage gap closes further in OECD countries, employers have fewer opportunities to hire women at a much lower salary in the expectation of increased profits. Furthermore, more educated women on the labour market imply a higher proportion of educated individuals in a country. This might have the effect of decreasing the relative salaries of the highly educated compared to those who are not. Another point to take into account is that at a certain female labour participation threshold, societies endow themselves with social policies such as childcare services and parental leaves that depend on the economic context. What happens then when there is a recession with the associated cuts in social services? How do households who had a child during the last burst of economic growth decide to behave? So again, what does this imply in terms of changes of the steady state levels of output per capita and productivity per worker compared to a situation in which women yet are educated but do not participate enough in the labour market to induce social changes as OECD countries have experience during the past 15 to 20 years? Clearly, a more complete (overlapping generations) model would include other feedback loops stemming from the stationary state of high income per capita, low fertility and high female participation. The types of interactions would involve different preferences, available choices and constraints, as well as income and substitution effects that appropriately describe the conditions that prevail in OECD countries. These would appropriately describe the transitions to the next steady states, following a perturbation in one of the degrees of freedom. This will remain, however, the focus of future analyses.

In terms of panel estimation, we have yet to define the correct specification to use and what interpretation should be given to the coefficients in the absence of a formal model that includes both the fertility and female market participation channels. Modelling the feedback loops described above and including (or not) fertility, education and female participation simultaneously on the right hand side of the regression is another point to be settled. In section 5.5 and appendix E, we include some of the preliminary results obtained from the techniques and data described in the next two sections.

3. The Data

Human capital indicators are based on the results of the 1994 International Adult Literacy Survey (IALS), which tested the skills of individuals aged between 16 and 65[14] over three domains of literacy – prose, quantitative and document. Synthetic time series for the 1960-1995 period were constructed from the cross-section data using the age distributions of test results, under the assumption that the level of human capital remains constant throughout individuals' lives.[15] The data is available for 14 countries[16] and can be broken by gender groups.

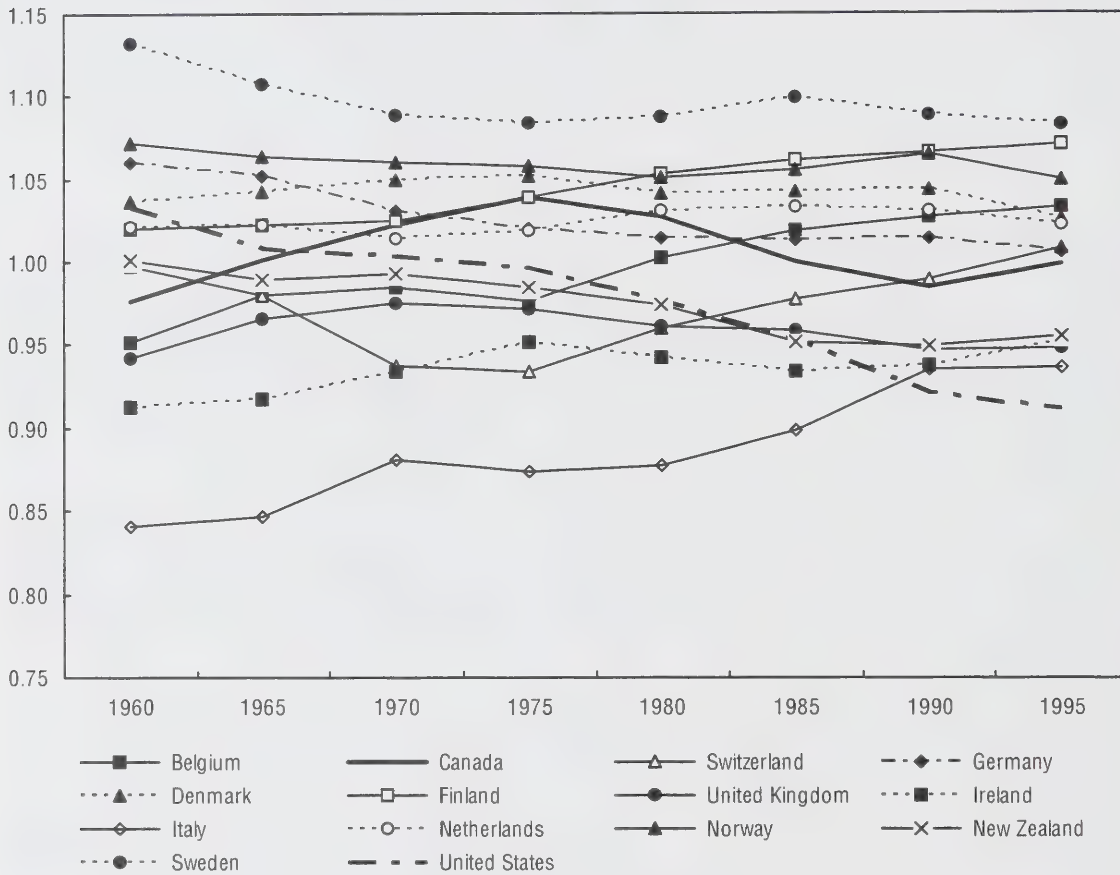
We use the literacy results of individuals aged 17 to 25 in a particular period as proxies for human capital investment during the previous period. Survey results are available both as average test scores and as percentages of individuals who have attained different literacy levels - 1 to 5 - thought to be associated with particular sets of skills. Both forms of survey results will serve as human capital indicators.

In contrast to human capital indicators based on schooling enrolment and attainment, these indicators provide a direct measure of the quality of human capital and are not subject to the usual problems related to the comparability of education systems across countries. However, the fact that the construction of the synthetic time series from the cross-section data cannot take account of migration flows over the period is an important drawback of our indicators. Moreover, our indicators impute levels of literacy to individuals earlier in their lives, without correcting for the adjustment in the quality of human capital that occurs during an individual's lifetime through learning and human capital depreciation. This is a disadvantage of our indicators relative to schooling data. If individuals' human capital tends to grow during post-school life, our indicators would tend to overestimate the human capital investment made before individuals entered the labour market.[17]

Average literacy scores of the population aged 17 to 25 relative to the cross-section mean are depicted in Figure 3.1. Scandinavian countries are performing very well. Sweden has had the highest average score throughout the period and Finland improved from 6th to 2nd place. Italy, which had the lowest score in 1960, improved substantially from 84% of the average to 94% in 1995. In contrast, the United States recorded the largest decline from 103% of the average to 91%, going from 5th to last place. The indicator for Canada is hump-shaped reaching a maximum in 1975.[18]

Figure 3.1

Average literacy score of population aged 17 to 25 relative to the cross-section mean



The data on GDP per capita, GDP per worker[19], investment as a share of GDP, imports and exports are from the Penn World Tables (version 6.1). These variables are expressed in purchasing power parities (PPP), which allows real quantity comparisons to be made across countries. GDP per capita is also adjusted for terms of trade changes. Tables A.1 and A.2 in Appendix A present the data on GDP per capita and GDP per worker, respectively. The openness ratio is the sum of exports and imports as a share of GDP, averaged over 5-year periods and adjusted for the size of countries measured by population and land area. Fertility rates are from the United Nations' database. Fertility and investment rates are also taken as averages over five year periods.

4. Empirical methodology

The relationship between various human capital indicators and economic growth is analysed using an empirical approach, the convergence-growth regression, which is based on the theoretical analysis of Mankiw, Romer and Weil (1992) and Barro and Sala-i-Martin (1992). Following Coulombe and Lee (1995), Islam (1995), and many subsequent studies, we pool time series and cross-country information in a panel data approach to study the convergence-growth relation.

4.1 Transformation of data and organization of the panel data bank

In the convergence-growth framework, the growth rate of the economic indicators such as GDP per capita, $Y_{i,T}$ for country i during period T is determined by the initial level of GDP per capita, by a set of environmental variables $Z_{i,T}$, and by a stochastic term $\varepsilon_{i,T}$ that captures the effect of country-specific shocks that temporarily affect the economy i during period t. In a pure cross-section setup of N countries covering the 1960-1985 period (such as in MRW, 1992), $\Delta Y_{i,T}$ is given by:

$$\Delta Y_{i,T} = F(Y_{i,0}, Z_i, \varepsilon_i).$$

Here, $\Delta Y_{i,T}$ is measured by the mean annual growth rate of Y for country i between 1960 and 1985, $Y_{i,0}$ is the initial level of GDP of country i, and Z_i are variables such as the investment ratio and the growth rate of population for country i. N is the total number of observations in the growth regression. In a pooled setup, $\Delta Y_{i,t}$ is given by:

$$\Delta Y_{i,t} = F(Y_{i,t-1}, Z_{i,t-p}, \varepsilon_{i,t}),$$

where $t = 1, \ldots, T$ and p is the number of lags (usually 0 or 1) used for the Z variables. As in Islam (1995) we will use five year time intervals between periods t and $t+1$. For values of p equal to 0 or 1, the panel setup will use NT observations between period 0 and period t.

The panel approach to growth regressions is now recognized as having numerous advantages over the pure cross-country approach that was first used by Barro (1991), Barro and Sala-i-Martin (1992) and MRW (1992), as discussed in Temple (1999), since it makes the best use of the information contained in the time series evolution of the cross-sections (countries, regions within a country) during the period under study. Furthermore, the pooling of time series and cross-sectional information is particularly welcome in the present empirical analysis given the limited number of cross-sections (14) covered by literacy data.

However, the combination of time series and cross-sectional information in growth regressions has to be done very carefully since the two types of information are not comparable in a straightforward manner. Common trends and common shocks (such as the productivity slowdown or the oil shock) to the Y and Z variables have to be extracted from the time series observations in order to obtain unbiased results. One approach to tackle this issue is, as in Coulombe and Lee (1995), Coulombe (2000, and 2003), de la Fuente (1998, and 2002) among others, is to define the

Y and *Z* variables as logarithm deviations from the cross-sectional sample mean:

$$x_{i,t} = \log\left(X_{i,t} \Big/ \sum_{i=1}^{N} \tfrac{1}{N} X_{i,t} \right),$$

where *X* is either *Y* or *Z*. The general structure of our empirical setup is then:

$$\Delta y_{i,t} = F(y_{i,t-1}, z_{i,t-p}, \varepsilon_{i,t}).$$

Here, *i*, 1, …, 14 for the 14 OECD countries in the sample and $t = 1, \ldots, 8$ where period 1 corresponds to 1960 and period 8 to 1995. To verify the robustness of the results and to allow comparisons with previous studies, alternative pooling will be performed with pools of 12 and 13 countries (excluding Belgium and/or Germany). Also, the pool of 14 countries will be used to perform estimations over the shorter 1960-1985 time interval, thus covering only six five-year periods.

The transformation of data in the pooled setup is also useful to partly address the problem of multicollinearity that arises in regressions of this type because the Z_i variables might be correlated. One well-known source of multicollinearity is the presence of common trends. The evolution of variables such as women's educational attainment, the fertility rate and the relative labour force participation of women has been affected since 1960 in developed countries by interrelated trends associated with the dynamic socio-economic evolution of gender relationships. The transformation of data eliminates common time trends and allows the analysis to concentrate on the cross-sectional information.

4.2 Investment in human capital and economic growth

The key assumption in Mankiw, Romer and Weil's (1992) pioneering empirical approach is that the measured fractions of a country's income invested in physical and human capital, $s(k)_i$ and $s(h)_i$ are steady state ratios. The growth rate of output is then related to the lagged level of output, to the two investment shares and to the growth rates of population, among other factors. The growth-regression equation tested in the first empirical setup is the following:

$$\Delta y_{i,t} = \varphi_1 y_{i,t-1} + \varphi_2 s(k)_{i,t} + \varphi_3 s(h)_{i,t} + \varphi_4 n_{i,t} + \varphi_{5,i} FE_i + \varepsilon_{i,t}, \qquad (1)$$

where the investment ratio variable $s(k)_{i,t}$ is the mean ratio of investment to GDP in period t, $n_{i,t}$ is either the mean rate of population growth or the fertility rate in period *t*, the FE_i are country specific fixed effects, and the $\varepsilon_{i,t}$ are additive error terms. The point estimate of the φ_1 parameter is a measure of the average speed of convergence across the 14 countries of the sample. Compared with MRW's (1992) original specification, given that our variables are all measured as logarithm deviations from the cross-sectional sample mean, this econometric setup implies that we assume equal growth rates of technological progress and equal depreciation rates across countries. Regressions will be done including and excluding fixed effects. The specifications with fixed effects allow, however, for different levels of technology across countries. The key variable in this empirical analysis are the $s(h)_{i,t}$ for which a variety of human capital investment indicators will be used including indicators based on literacy scores and others based on enrolments. The measures of human capital investment derived from literacy data for the period 1960-1965 (period 1) are based in this empirical setup on literacy scores for the 17 to 25 age group in 1960.

In the setup of equation 1, MRW (1992) show that the share of physical capital and human capital in national income, α and η respectively, could be computed from the point estimates of φ_1, φ_2, and φ_3 since:

$$\varphi_2 = -\varphi_1\left(\frac{\alpha}{1-\alpha-\eta}\right) \qquad (2)$$

$$\varphi_3 = -\varphi_1\left(\frac{\eta}{1-\alpha-\eta}\right) \qquad (3)$$

We will be using these relations to provide estimates of human (and physical) capital shares for a variety of human capital indicators.

4.3 Education as a proxy of long run steady states

As shown in the work of Barro and Sala-i-Martin (1995), there is no reason to restrict the set of environmental variables Z to the usual one implied by the simple augmented Solow growth model, i.e. population growth (or fertility) and investment ratios for physical and human capital. Other variables that might affect the production function have proved successful in explaining long run cross-country differences. In this general growth regression setup, our human capital indicators (investment or stock data) might be viewed as one fundamental determinant, among others, of the long run steady state. The starting point of their approach to conditional convergence is the following basic equation derived from a log-linearization around the steady state (for periods of unit length):

$$\log(Y)_{i,t} = e^{-\beta}\log(Y)_{i,t-1} + (1-e^{-\beta})\log(Y^*(Z_i)) + \varepsilon_{i,t},$$

where β is the speed of convergence toward the steady state Y_i^*, which has to be estimated from its determinants Z_i. This dynamic equation implies that at time t, the evolution of GDP per capita in country i is a weighted average of its initial and steady state levels. The growth rate of $Y_{i,t}$ is thus an increasing function of the gap between the steady state and the initial position. In terms of logarithm deviations from the cross-sectional sample mean, this equation implies the following forms for the growth regression equation used in our empirical analysis:

$$\Delta y_{i,t} = \varphi_1 y_{i,t-1} + \varphi_2 s(k)_{i,t} + \varphi_3 s(h)_{i,t} + \varphi_4 n_{i,t} + \varphi_6 open_{i,t} + \varphi_{5,i} FE_i + \varepsilon_{i,t}, \quad (4)$$

where $open_{i,t}$ is the (adjusted) openness ratio variable as in Barro (2001). The $s(h)$, $s(k)$, n, $open$, and FE are the z_i determinants of the relative long run steady states y_i^*. Here again, the key variable in this empirical analysis is $s(h)_{i,t}$, for which a variety of human capital indicators will be used, including indicators based on literacy scores and others based on schooling. Equation 4 will be estimated using the panel data organisation with periods of five years implied by equation 1.

The long run level effect of a permanent shock to z_i can be computed from the long run solution to equation 4, where $\Delta y_{i,t} = 0$ at $y = y^*$. Thus, the long run elasticities for the various z are:

$$\frac{\partial y_i^*}{\partial z_i^*} = -\frac{\hat{\varphi}_{z,i}}{\hat{\varphi}_1} \qquad (5)$$

4.4 Details on the estimation techniques

Many alternative estimation techniques are available for pooled time series cross-section observations in convergence-growth regressions. Appropriate econometric techniques are used to tackle various heteroskedasticity problems underlying this type of panel analysis. The first set of results comes from generalized least-squares (GLS) estimations using cross-sectional weighted regressions to account for cross-sectional heteroskedasticity. Furthermore, we computed White heteroskedasticity consistent standard errors (HCCME) that allow for asymptotically valid inferences in the presence of the remaining time series heteroskedasticity. The second set of results using system estimations with instrumental variables (IV) were performed with weighted two-stage least squares (WTSLS) again to account for cross-sectional heteroskedasticity. In both cases, when possible under convergence condition, we used iterative techniques for updating coefficients and the weighting matrix. These estimates are respectively labelled in the tables as iterated feasible generalized least-squares (IFGLS) and iterative weighted two-stage least squares with instrumental variables (IWTSLS-IV).

It was not possible to perform more general methods of estimation such as "seemingly unrelated regression estimation" (SUR) and three-stage least squares (which is an IV approach to SUR) given that the number of time series was smaller than the number of cross-section observations at hand.

5. Results

5.1 Regressions without the openness variables

Regression results for the conditional convergence of GDP per capita, following equation 1 of the MRW/Islam setup and using average test scores of the population aged 17 to 25 as human capital investment measures, are displayed in Table 5.1. The estimated convergence speeds are highly significant and correspond to annual rates of around 6.5 percent, which are higher than that estimated by MRW (1992) for their OECD sample but somewhat below those obtained by Islam (1995).[20] Most importantly, the human capital indicators are all significant at the 5 percent level, except the one based on document skills when estimated with IFGLS. Investment rates are highly significant in all regressions but fertility rates are not, although they have a negative sign as predicted by the neoclassical growth framework.

Table 5.1

Conditional convergence of GDP per capita, 1960 to 1995

Human capital investment measured by average test scores of the population aged 17 to 25

Dependent variable : Log difference of GDP per capita				
Independent variables	Literacy	Prose	Quantitative	Document
		IFGLS		
Initial GDP	-0.056 ***	-0.058 ***	-0.056 ***	-0.054 ***
	(0.014)	(0.014)	(0.014)	(0.014)
Literacy	0.074 **	0.079 **	0.070 **	0.068 *
	(0.034)	(0.032)	(0.033)	(0.035)
Investment rate	0.043 ***	0.046 ***	0.041 ***	0.043 ***
	(0.007)	(0.007)	(0.007)	(0.007)
Fertility rate	-0.009	-0.008	-0.008	-0.010
	(0.010)	(0.009)	(0.010)	(0.009)
R^2	0.52	0.53	0.52	0.52
Elasticities (K; H)	(0.77; 1.32)	(0.79; 1.36)	(0.73; 1.25)	(0.80; 1.26)
Implied (α; η)	(0.25; 0.43)	(0.25; 0.43)	(0.25; 0.42)	(0.26; 0.41)
		IWTSLS-IV		
Initial GDP	-0.058 ***	-0.060 ***	-0.058 ***	-0.056 ***
	(0.011)	(0.011)	(0.012)	(0.011)
Literacy	0.091 **	0.092 ***	0.086 **	0.086 **
	(0.035)	(0.034)	(0.035)	(0.036)
Investment rate	0.045 ***	0.047 ***	0.042 ***	0.044 ***
	(0.008)	(0.009)	(0.008)	(0.008)
Fertility rate	-0.006	-0.005	-0.006	-0.007
	(0.008)	(0.008)	(0.008)	(0.008)
Elasticities (K; H)	(0.78; 1.57)	(0.78; 1.53)	(0.72; 1.48)	(0.79; 1.54)
Implied (α; η)	(0.23; 0.47)	(0.24; 0.46)	(0.23; 0.46)	(0.24; 0.46)

Notes: The regressions include country fixed effects. There are 96 observations in each regression. White heteroskedasticity standard errors are shown in parentheses below the estimated coefficients. *: significant at 10% level; ** at 5% level; *** at 1% level. Instruments used for the IWTSLS-IV estimations are initial GDP per capita and the lagged values of the investment rate, of the fertility rate and of the de la Fuente and Doménech average schooling years variable. No significant serial correlation in all regressions.

Point estimates of the various parameters are very similar across comparable IFGLS and IWTSLS-IV regressions. Interestingly however, it appears that the effects of various literacy measures are estimated more precisely with IWTSLS-IV than with IFGLS when lagged schooling (taken from de la Fuente and Doménech data bank) are used as instruments with lagged GDP, fertility, and investment ratios. Broadly speaking, the presence of an endogenous variable on the right-hand side of a regression without IV might translate into both biased estimates and variance problems. In our specific case, it appears that the point estimates of the various parameters are not biased with IFGLS but they can be more accurately estimated with the IWTSLS-IV technique.

Note that, although the estimated coefficient on literacy is positive and significant, the direction of the causality between per capita GDP growth and literacy is *a priori* unclear. Both the initial level of GDP per capita and the literacy indicator are used as explanatory variables, although the level of GDP per capita is itself a function of human capital. In fact, in an open economy with perfect capital mobility for the financing of physical capital, the level of GDP per capita is determined entirely by the stock of human capital, and the convergence of GDP per capita is determined by the convergence of the human capital stock (Barro, Mankiw and Sala-i-Martin, 1995). Human capital may also drive economic growth if, for example, highly educated individuals are attracted and able to migrate to more prosperous countries, or if economic growth generates human capital through learning-by-doing. The possibility of reverse causality is particularly relevant in our analysis, given that our human capital investment measures are based on literacy tests performed at the end of the period of analysis, and are therefore somewhat distorted, among other things, by the migration flows that occurred over the period.

Under the assumption that the economies are in their steady state, we can compute the shares of physical and human capital retribution in national income, implied by the regression results as shown in equations 2 and 3. For both IFGLS and IWTSLS-IV estimations and the four literacy measures, these implied shares are around 0.25 and 0.45 for physical and human capital respectively. This estimated share of physical capital is roughly consistent with the observed share of profits in national income of developed countries, which is typically around 30 percent and fairly constant over time. The shares implied by our regression results leave about 30 percent of national income for the retribution of raw labour, which implies that 2/5 of wages correspond to the retribution of raw labour and 3/5 represent the returns to skills. These results on the human capital share are consistent with the findings of Mankiw (1995) and Coulombe and Tremblay (2001).

For the sake of comparison with some of the pioneering studies in this literature, including Mankiw, Romer and Weil (1992) and Islam (1995), we have also conducted the same regressions for the 1960-1985 period with and without country fixed effects, and for the 1960-1995 period without fixed effects. Results for IFGLS estimations are reported in Appendix B. The interesting point to note is that the estimated effect of human capital investment on growth is stronger when the period of analysis is limited to 1960-1985. For this period, the literacy indicators' point estimates are all significant at the 5 percent level even when the growth regressions are estimated without country fixed effects. For the 1960-1995 period however, the literacy indicators' point estimates have the expected sign but are not significant without country fixed effects.

Country fixed effects that account for various forms of heterogeneity across countries are included in all the remaining regressions. They clearly improve the precision of the estimated effect of human capital indicators, among others. They could also account for heterogeneity in the quality of the literacy data across countries. For example, contrary to other countries for which the coverage is complete, literacy data for Belgium cover only the population from the (relatively rich and educated) Flanders region. Of course, the GDP data refer to the whole country and the relationship between literacy and GDP growth might be substantially different for Belgium. Not surprisingly, the fixed effect for Belgium is always negative and significant (with p values around 1percent) indicating that overall country's growth (including Flanders and Walloon) is overestimated by the independent variable (excluding fixed effects) since the literacy indicators are based only

on the rich region. In regressions using the de la Fuente and Doménech (2002) data on schooling analysed below, Belgium's fixed effect is not even significant at the 10 percent level.

5.2 GDP per capita versus labour productivity

Following Barro (2001), we have included the openness ratio in our conditional convergence regressions based on the econometric set up of equation 4 in all the following regressions.[21] Results for the convergence of GDP per capita and GDP per worker are presented in Tables 5.2 and 5.3, respectively. In all regressions dealing with labour productivity growth, Germany had to be excluded from the sample since the time series is not available for the whole country prior to the reunification in 1990. The openness ratio is highly significant in all cases. Moreover, its inclusion in the convergence regressions of GDP per capita leads to higher point estimates and statistical significance for both speeds of convergence and human capital indicators.

Table 5.2

Conditional convergence of GDP per capita, 1960 to 1995

Human capital investment measured by average test scores of the population aged 17 to 25

Dependent variable : Log difference of GDP per capita				
Independent variables	Literacy	Prose	Quantitative	Document
		IFGLS		
Initial GDP	-0.065 ***	-0.066 ***	-0.066 ***	-0.062 ***
	(0.013)	(0.013)	(0.013)	(0.013)
Literacy	0.096 ***	0.098 ***	0.093 ***	0.087 **
	(0.035)	(0.033)	(0.033)	(0.037)
Investment rate	0.037 ***	0.040 ***	0.034 ***	0.037 ***
	(0.008)	(0.008)	(0.008)	(0.008)
Fertility rate	-0.016 *	-0.016 *	-0.015	-0.016 *
	(0.009)	(0.009)	(0.009)	(0.009)
Openness ratio	0.021 ***	0.021 ***	0.022 ***	0.020 **
	(0.007)	(0.007)	(0.007)	(0.008)
R^2	0.56	0.57	0.57	0.55
Elasticities (K; H)	(0.57; 1.48)	(0.61; 1.48)	(0.52; 1.41)	(0.60; 1.40)
		IWTSLS-IV		
Initial GDP	-0.065 ***	-0.067 ***	-0.067 ***	-0.063 ***
	(0.011)	(0.011)	(0.011)	(0.011)
Literacy	0.099 ***	0.102 ***	0.098 ***	0.087 **
	(0.035)	(0.033)	(0.034)	(0.036)
Investment rate	0.038 ***	0.042 ***	0.035 ***	0.037 ***
	(0.009)	(0.009)	(0.008)	(0.009)
Fertility rate	-0.016 *	-0.016 *	-0.016 *	-0.017 *
	(0.008)	(0.008)	(0.009)	(0.009)
Openness ratio	0.022 ***	0.021 **	0.023 ***	0.021 **
	(0.008)	(0.008)	(0.008)	(0.008)
Elasticities (K; H)	(0.58; 1.52)	(0.63; 1.52)	(0.52; 1.46)	(0.59; 1.38)

Notes: The regressions include country fixed effects. The IFGLS and IWTSLS-IV regressions have 95 and 94 observations, respectively. White heteroskedasticity standard errors are shown in parentheses below the estimated coefficients. *: significant at 10% level; ** at 5% level; *** at 1% level. Instruments used for the IWTSLS-IV estimations are initial GDP per capita and the lagged values of the investment rate, of the fertility rate, of the openness ratio and of the de la Fuente and Doménech average schooling years variable. No significant serial correlation in all regressions.

Table 5.3

Conditional convergence of GDP per worker, 1960 to 1995

Human capital investment measured by average test scores of the population aged 17 to 25

Dependent variable : Log difference of GDP per worker				
Independent variables	Literacy	Prose	Quantitative	Document
		IFGLS		
Initial GDP	-0.049 ***	-0.051 ***	-0.049 ***	-0.048 ***
	(0.010)	(0.010)	(0.011)	(0.010)
Literacy	0.121 ***	0.124 ***	0.110 ***	0.118 ***
	(0.034)	(0.031)	(0.034)	(0.035)
Investment rate	0.036 ***	0.039 ***	0.032 ***	0.037 ***
	(0.008)	(0.008)	(0.008)	(0.008)
Fertility rate	-0.002	-0.003	-0.001	-0.002
	(0.009)	(0.009)	(0.009)	(0.009)
Openness ratio	0.036 ***	0.036 ***	0.036 ***	0.036 ***
	(0.006)	(0.007)	(0.006)	(0.006)
R^2	0.66	0.66	0.66	0.66
Elasticities (K; H)	(0.73; 2.47)	(0.76; 2.43)	(0.65; 2.24)	(0.77; 2.46)
		IWTSLS-IV		
Initial GDP	-0.051 ***	-0.052 ***	-0.050 ***	-0.049 ***
	(0.010)	(0.010)	(0.010)	(0.010)
Literacy	0.114 ***	0.120 ***	0.102 ***	0.110 ***
	(0.037)	(0.036)	(0.036)	(0.038)
Investment rate	0.033 ***	0.037 ***	0.028 ***	0.033 ***
	(0.010)	(0.010)	(0.009)	(0.010)
Fertility rate	-0.009	-0.010	-0.008	-0.009
	(0.009)	(0.009)	(0.009)	(0.009)
Openness ratio	0.039 ***	0.039 ***	0.040 ***	0.039 ***
	(0.007)	(0.007)	(0.007)	(0.007)
Elasticities (K; H)	(0.65; 2.24)	(0.71; 2.31)	(0.56; 2.04)	(0.67; 2.24)

Notes: The regressions include country fixed effects. The IFGLS and IWTSLS-IV regressions have 90 and 89 observations, respectively. The pool excludes Germany. White heteroskedasticity standard errors are shown in parentheses below the estimated coefficients. *: significant at 10% level; ** at 5% level; *** at 1% level. Instruments used for the IWTSLS-IV estimations are initial GDP per capita and the lagged values of the investment rate, of the fertility rate, of the openness ratio and of the de la Fuente and Doménech average schooling years variable. No significant serial correlation in all regressions.

Also reported in Tables 5.1 to 5.3 are the long run elasticities of GDP per capita and GDP per worker with respect to physical and human capital accumulation implied by the regression results following equation 5. However, before interpreting these results, it is important to point out that as long as the convergence speed is positive and significantly different from zero, variables like fertility, literacy (human capital), or the investment rate might only have a level effect in the long run on GDP per capita or labour productivity. Convergence is an essential property of neoclassical growth models and follows from decreasing marginal returns to capital (human and physical) accumulation. In this framework, only the growth rate of technological progress determines the steady state growth rate of labour productivity. But in growth regressions, the convergence speed is typically rather slow, between 2 and 6 percent per year. Consequently, a positive shock to human capital formation, initiated from a successful change in policy for example, will only affect, in the long run, the relative labour productivity level, not the growth rate. Since the convergence speed is slow, it takes a long time period to reach the new steady state and the transitory effect of the human capital shock on labour productivity lasts for a concomitantly long time. Following a human capital shock, with convergence speeds of 2 and 6 percent, the economy will respectively need 35 and 11.66 years to close half of the gap to the new steady state. In a slow

convergence world, the difference between long run growth and level effects is not that important. However, it is more accurate to measure the impact of a shock by its long run accumulated effect on the steady state level of labour productivity, as it is done in this paper, rather than looking at the impact measured by the point estimate of the human capital variable, as done in many other studies. When the right-hand side variables are changed in growth regressions, the convergence speed is also affected and so comparing two human capital indicators' point estimates obtained from the two different regressions can be misleading.

Hence, the elasticities implied by our regression results based on average test scores of 17 to 25 year olds indicate that the long run effects of human capital investment in literacy are much more important – around three times – than investment in physical capital. A country that achieves literacy scores one percent higher than the average ends up in a steady state with labour productivity and GDP per capita respectively higher than other countries by 2.5 and 1.5 percent on average. This result holds whether literacy is measured by prose, quantitative or documents skills. As it will be shown in section 5.6 below, it is important to point out that this result is not independent of the scale used to report literacy scores. Furthermore, this does not mean that the economic returns for investing in literacy are much higher than for physical capital (for which the long run elasticities are 0.73 and 0.57 for labour productivity and GDP per capita) because the cost of increasing the average literacy score by one percent at the national level may be much higher than the cost of increasing physical capital by the same amount.

It is interesting to note that the long run elasticities and the R^2 are higher, and the parameters are generally estimated with more accuracy (smaller p value) in the regressions dealing with labour productivity rather than GDP per capita. Two reasons might help explaining these results. First, the underlying theoretical framework applies both to GDP per capita and labour productivity when the unemployment rate and participation ratio are on steady state paths. When they are not, the convergence-growth theoretical framework applies, strictly speaking, only to labour productivity. This relative performance of growth regressions based on labour productivity might, therefore, be driven by the large swings observed in employment and participation rates in OECD countries during the period under study. The fact, however, that the literacy variables are significant for both GDP per capita and productivity growth indicates some robustness of the relationship linking literacy and growth. Second, the regressions using labour productivity excludes Germany since the productivity data is not available for the whole country prior to reunification. Robustness analysis in Appendix E indicates that the GDP per capita regressions also produce higher long run elasticities for human capital indicators, more precise estimates, and higher R^2 when Germany is excluded from the sample.

We also note that labour productivity converges, on average, at a lower speed than GDP per capita. The average annual convergence speeds for these two indicators are 5.5 percent and 7.9 percent.

5.3 De la Fuente and Doménech corrected schooling data

Table 5.4 reports results for the conditional convergence of GDP per capita and GDP per worker, using average years of schooling in the population as measures of human capital, taken from the de la Fuente and Doménech data set. In the regressions reported in the first and third columns, literacy is not included in the set of independent variables. In this case, average years of schooling has a positive and marginally significant effect (p-value of 5.6 percent) on per capita GDP growth, but not on labour productivity. Thus, our measures of literacy appear to perform better than schooling data, possibly reflecting the fact that they are more direct measures of human capital.

Still, there are methodological differences that should be noted. First, the de la Fuente and Doménech growth regressions do not include the openness ratio and use the growth rate of the population, rather than the fertility rate. Second, in contrast to our approach of measuring all variables as deviations from the mean, they use time dummies in order to remove common trends,

which will tend to produce higher R^2 since their time dummies are found to be highly significant. Finally, their sample consists of 21 OECD countries, including countries that have experienced an important catch-up toward the OECD mean level during the period, such as Greece, Portugal and Spain. These three countries, unfortunately, are not part of the sample of 14 countries treated in this analysis.[22 23]

The regressions reported in the second and fourth columns include both the de la Fuente and Doménech schooling measure and our literacy measure based on average test scores of the population aged 17 to 25. In this case, the average years of schooling does not have a significant effect on either GDP per capita growth or labour productivity growth, while the literacy measure has a positive effect, significant at the 5 % level on the growth of GDP per capita and at the 1 % level on the growth of productivity.

Table 5.4

Conditional convergence of GDP per capita and GDP per worker, 1960 to 1995

Average years of schooling of the population aged 25 and over taken from the de la Fuente and Doménech data set and literacy measured by average test scores of the population aged 17 to 25

Dependent variable :	Log difference of GDP per capita		Log difference of GDP per worker	
Initial GDP	-0.076 ***	-0.068 ***	-0.037 **	-0.041 ***
	(0.014)	(0.014)	(0.014)	(0.012)
Average years of schooling	0.057 *	0.019	-0.011	-0.057
	(0.029)	(0.034)	(0.039)	(0.035)
Literacy		0.085 **		0.146 ***
		(0.040)		(0.035)
Investment rate	0.032 ***	0.038 ***	0.024 **	0.033 ***
	(0.009)	(0.008)	(0.010)	(0.008)
Fertility rate	-0.015	-0.016	-0.006	0.004
	(0.010)	(0.010)	(0.009)	(0.009)
Openness ratio	0.018 **	0.021 ***	0.031 ***	0.033 ***
	(0.007)	(0.007)	(0.009)	(0.005)
R^2	0.54	0.56	0.59	0.67
Elasticities (K; H)	(0.42; 0.75)		(0.65; -0.30)	

Notes: The regressions include country fixed effects. There are 95 and 90 observations for GDP per capita and GDP per worker, respectively. White heteroskedasticity standard errors are shown in parentheses below the estimated coefficients. *: significant at 10% level; ** at 5% level; *** at 1% level. The regression of GDP per worker excludes Germany. No significant serial correlation in either regression.

5.4 Percentage of the population that achieved specific literacy levels

Table 5.5 reports the results of conditional convergence regressions in which the human capital measures are based on the percentages of individuals that attained at least level 4 on a particular literacy test. Only the indicator based on prose skills is found to have a significant effect on growth, and the point estimates/long run elasticities of these human capital measures are much lower than those based on average scores, for each of the prose, quantitative and document literacy domains. These results suggest that measures based on the average test scores over all individuals are much better indicators of the aggregate level of human capital investment than measures based on the proportion of individuals that achieved relatively high levels of literacy.

This finding also implies that the distribution of human capital investment may be important for long run standards of living. In particular, it is consistent with the view that human capital investment fosters growth mostly by making the overall labour force more productive, as opposed to developing highly talented individuals who may, among other things, have a positive impact on growth through their contribution to innovation and technological progress.

Appendix C reports the results of regressions of GDP per capita using the proportion of men and women that achieved at least level 4 on the literacy tests as human capital measures. In both cases, the estimated long run elasticity of GDP per capita is much lower than that for average literacy scores. Interestingly, the share of women that achieved at least level 4 is found to have a greater impact on growth than the share of men.

We also ran a series of regressions in which we included the share of individuals that achieved only level 1 and at most level 2 as explanatory variables, as opposed to the share of the population that achieved at least level 4. Relative to the cross-country average, these measures may be seen as indicators of under-investment in human capital, which may act as a drag on growth. Results for the percentage of individuals that achieved level 1 only are reported in Table C.3 in Appendix C. For these indicators, we found that the lack of investment in the prose skills of the population and in all three types of literacy skills of men had a negative and significant effect on the growth of GDP per capita. The prose skills of women had a negative and significant effect at the 10% level. For GDP per worker, the document skills of men and the prose skills of women were found to have a negative and significant effect on growth. The percentage of individuals that achieved at most level 2 does not have a significant effect on growth, although the point estimates are always negative. Let us now turn to the analysis of the differential gender effects, but based on average test scores.

Table 5.5

Conditional convergence of GDP per capita, 1960 to 1995

Human capital investment measured by the share of the population aged 17 to 25 that achieved at least level 4

Dependent variable : Log difference of GDP per capita			
Independent variables	Prose	Quantitative	Document
		IFGLS	
Initial GDP	-0.070 ***	-0.065 ***	-0.064 ***
	(0.012)	(0.014)	(0.014)
Literacy	0.008 ***	0.006	0.005
	(0.003)	(0.004)	(0.004)
Investment rate	0.037 ***	0.026 ***	0.029 ***
	(0.008)	(0.007)	(0.008)
Fertility rate	-0.014	-0.015	-0.015
	(0.009)	(0.010)	(0.010)
Openness ratio	0.021 ***	0.020 **	0.017 **
	(0.007)	(0.008)	(0.008)
R^2	0.56	0.54	0.53
Elasticities (K; H)	(0.53; 0.11)	(0.40; 0.09)	(0.45; 0.08)
		IWTSLS-IV	
Initial GDP	-0.070 ***	-0.066 ***	-0.065 ***
	(0.011)	(0.012)	(0.012)
Literacy	0.009 ***	0.007	0.005
	(0.003)	(0.004)	(0.004)
Investment rate	0.039 ***	0.025 ***	0.029 ***
	(0.009)	(0.007)	(0.008)
Fertility rate	-0.013	-0.015	-0.016 *
	(0.009)	(0.009)	(0.009)
Openness ratio	0.021 ***	0.022 ***	0.019 **
	(0.008)	(0.008)	(0.008)
Elasticities (K; H)	(0.56; 0.13)	(0.38; 0.11)	(0.45; 0.08)

Notes: There are 95 and 94 observations in each IFGLS and IWTSLS-IV regression, respectively. White heteroskedasticity standard errors are shown in parentheses below the estimated coefficients. *: significant at 10% level; ** at 5% level; *** at 1% level. Instruments used for the IWTSLS-IV estimations are initial GDP per capita and the lagged values of the investment rate, of the fertility rate and of the de la Fuente and Doménech average schooling years variable. No significant serial correlation in all regressions.

5.5 Results based on Female versus Male Literacy

Since the average literacy scores were available by gender, we first decided to enter both literacy variables for male and female on the right hand side of our growth regressions (unreported regressions). In all cases, the literacy score based on female population was positive and highly significant while the point estimate of male literacy was insignificant (sometimes with the unexpected sign!). We further discover that the good results of literacy scores for the overall population on GDP per capita (and to a lesser extent for productivity) were driven by the female component. This was one of the big surprises of our empirical analysis, and it led us to try a different econometric setup in order to understand what was going on.

So, in order to compare the relative contribution to growth of investment in the human capital of men and women, we analysed the conditional convergence of GDP per capita and of labour productivity, using separately the average literacy scores of men and women as human capital investment measures. In order to control for the effect of women's literacy on their labour market participation, we also included, as an additional regressor, the participation rate of women relative to that of men. The long run elasticities of GDP per capita and labour productivity with respect to investment in the human capital of men and women are presented in Table 5.6. The detailed regression results are contained in Appendix D.

Undoubtedly, investment in the human capital of women appears to have a much stronger effect on subsequent growth than investment in the human capital of men. For both GDP per capita and GDP per worker, both estimation techniques and all four measures of human capital investment, long run elasticities are always larger and more significant for the literacy levels of women. While investment in the literacy of men only has a significant effect at the 5 percent level on the growth of productivity, investment in women's literacy has a significant effect at the 1 percent level on both productivity growth and GDP per capita growth. R^2 are also substantially higher than in our previous regressions. They are in the neighbourhood of 0.60 and 0.75 for the convergence of GDP per capita and labour productivity, respectively.

Note as well that in the case of men's literacy, document skills seem to be less important than prose and quantitative skills. In the case of women's literacy, prose skills have the largest impact on GDP per capita, while quantitative skills seem to be relatively more important for productivity.

Since our regressions control for the fertility rate and the relative women labour market participation rate, the estimated effect of women literacy on growth is independent of the impact of lower fertility and higher labour market participation that may result from investment in women's education.

Table 5.6

Long run elasticity of GDP per capita and GDP per worker with respect to human capital investment measures

	Literacy IFGLS	Literacy IWTSLS-IV	Document	Prose	Quantitative
GDP per Capita					
Men	0.82 *	0.81	0.63	0.88 *	0.88 *
R^2	[0.58]		[0.57]	[0.57]	[0.59]
Women	1.23 ***	1.23 ***	1.20 ***	1.30 ***	1.10 ***
R^2	[0.60]		[0.58]	[0.60]	[0.60]
GDP per Worker					
Men	1.04 **	1.08 **	0.91 *	1.07 **	1.02 **
R^2	[0.73]		[0.72]	[0.73]	[0.74]
Women	1.49 ***	1.51 ***	1.25 ***	1.36 ***	1.77 ***
R^2	[0.75]		[0.73]	[0.78]	[0.76]

Notes: There are respectively 89 and 90 observations in each IWTSLS-IV and IFGLS regression. Regressions based on prose, quantitative and document skills are estimated with IFGLS. The pool of countries excludes Germany for the regression of productivity growth. *: Significant at 10% level; ** at 5% level; *** at 1% level. The set of independent variables includes the initial GDP per capita, the investment rate, the openness ratio, the fertility rate, literacy measure and women labour force participation. Instruments used for the IWTSLS-IV estimations are initial GDP per worker and the lagged values of the investment rate, of the openness ratio, of the fertility rate, of the de la Fuente and Doménech average schooling years variable and of the labour force participation of women. The long run elasticity is defined as the ratio of minus the coefficient on the literacy variable to that of initial GDP per capita - or per worker -obtained from an IFGLS or IWTSLS-IV regression.

Appendix E presents the results of a robustness analysis in which estimations were repeated with the same set of independent variables, but in which one country was removed from the sample each time. The results indicate that three variables exhibited strong robustness and are almost not affected by the sample adjustment. These variables are the initial level of GDP per capita or labour productivity, the investment ratio and literacy when it is measured by the scores obtained by women only. The literacy of both men and women combined does not have a significant effect on growth when the UK is excluded from the sample. In this case, the literacy indicator still has a positive sign but its p-value equals 0.12 and 0.30 with GDP per capita and per worker as dependent variables, respectively. In all other cases, however, the literacy of the total population is significant at the 5 percent level. We will come back to the robustness analysis in the conclusion.[24]

Different explanations could potentially account for the greater effect of investment in women's literacy, as opposed to men literacy. First, to the extent that there were initially social barriers to the education of women, investment in the literacy of women may have been provided to relatively high ability individuals. The more able women were more likely to overcome barriers to education and labour market participation. Thus, there could have been a *selection effect* through which new human capital was combined with individuals of higher innate potential, on average in the case of women as opposed to men.

Second, the rate of return on women's human capital investment may have been high because the initial level of literacy was relatively low among women. Because of diminishing returns, the marginal increase in the productivity of labour that results from an increase in human capital is higher for individuals with low initial levels of human capital. So, provided that there were barriers to women's education, investment in women's literacy may have had a greater impact on GDP because of this *marginal return effect*. Note that these first two interpretations concord with Psacharopoulos' (1994) finding on rates of return to education by sexes.

Third, men and women may have comparative advantages in certain types of occupations (Galor and Weil, 1996), if for example, men tend to be relatively more productive in manual occupations that require more physical strength. If this is the case, women may have a comparative

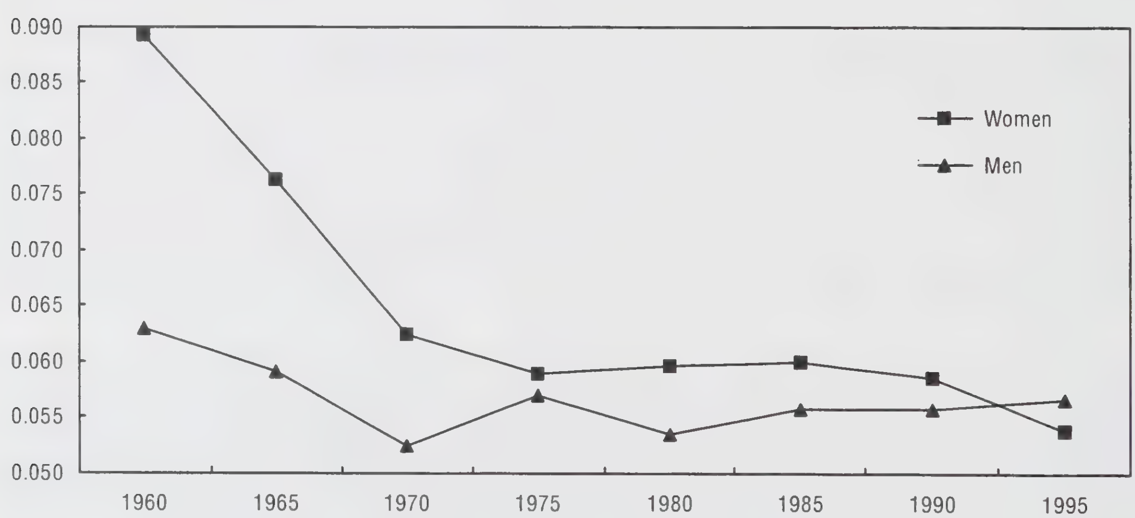
advantage in occupations that require high levels of human capital. As a result, the optimal stock of human capital would be higher for women than it is for men. Therefore, even if the average levels of human capital were initially equal for men and women, because of this *comparative advantage effect*, we should expect higher macroeconomic returns from investment in the human capital of women and the resulting reallocation of labour across different types of occupations.[25]

Fourth, if male and female labour are not perfect substitutes, the relatively low initial literacy level of women may have resulted in an *imbalance effect* between physical and human capital. Because of the complementarity between physical and human capital in the production process, and decreasing marginal returns to the accumulation of each type of capital, the neoclassical growth framework predicts that the economy will grow faster the further away the ratio of human to physical capital is from its steady state level, whether above or below (Barro and Sala-i-Martin, 1995). The imbalance between the two capital stocks implies a relatively high marginal return on the one which is relatively scarce and its accumulation induces rapid growth. Therefore, investment in the human capital of women may have had a larger effect on growth than investment in the human capital of men, because women's labour was combined with an unbalanced stock of human and physical capital.

Fifth, the precision of the estimation of the impact of human capital variables on growth (and to some extent robustness) depend on the time series and cross-sectional variations of the human capital variables. As shown by Figure 5.1, there is more variation across countries in women's literacy scores than for men at the beginning of the sample and the cross-sectional variation of the two indicators is roughly the same at the end of the sample. This statistical effect, illustrated by the larger sigma-convergence of the female indicator, might by itself account for the measured gender-gap effect. This point is even more important given that the countries that have experienced the most notable catch-up toward the OECD mean during the period under study, namely Greece, Portugal and Spain, are not in the sample currently under study.

Figure 5.1

Standard deviation of the logarithm of average literacy scores relative to the cross-section mean



Finally, women's literacy could also capture the effects of omitted variables such as the level of social infrastructure (Hall and Jones, 1999) and social development of a country. Social infrastructure is a concept that is very hard to measure directly and it has not yet been entered as independent variables in cross-country growth regressions. In their cross-country growth accounting approach, Hall and Jones (1999) use social infrastructure to account for the large differences in the Solow residual across developed and less-developed countries. They argue that the level of social infrastructure across countries is mainly determined by history, location, and language. In keeping with this argument it is possible to interpret the strong and robust effect of female literacy in our study by arguing that female literacy (compared to male) is also a determinant of social infrastructure. It will be interesting in further research to explore this hypothesis by using literacy score data in Hall and Jones' growth accounting approach.

5.6 Alternative scaling

The use of literacy test scores as indicators of cross-country relative human capital investment in the preceeding econometric analysis is based on the assumption that the 0 to 500 scale used to measure test scores is an absolute scale. Under this assumption, a zero score in the proficiency scale is an indication of zero investment in human capital. We complete the empirical analysis by investigating whether the general direction of results is affected by the use of alternative scaling.

The first alternative scale (labeled alternative scale 1 in Table 5.7) has been provided by Fernando Cartwright from the Centre for Education Statistics at Statistics Canada. With this scale, the measure of literacy is transformed to reflect the average national odds of success on a literacy task for a particular cohort. Geometric cross-country means are used for the cross-sectional demeaning transformation of the data. For the second alternative scale (alternative scale 2 in Table 5.7), we have simply redefine the original scale by assuming that a score 100 is the absolute zero. Under this assumption, a score of 100 is an indication of zero investment in human capital.

The results of regressions using the benchmark specification for both alternative scales are compared to the results using the original scale in Table 5.7 for the male and female case. The first finding of interest is that the point estimates of the literacy variable are smaller with the new scales. This is not surprising since both rescaling increases the cross-section and time series variances of the literacy variable. This point however illustrates that the long-run elasticities estimated for the literacy variable have to be interpreted in the framework of the specific scaling used to report literacy test scores.

The key finding of interest of this exercise is related to the t-statistics for the literacy variable. In the regression using male literacy, the t-statistics decrease (substantially) with the alternative scale 1 and increase (somewhat marginally) with the alternative scale 2. In the case of female, the effect of both rescaling is to increase the t-statistics of the literacy variable.

Two important points come out of this exercise. First, again the analysis indicates that results for the effect of literacy on growth are more robust for female than for male. Second, more research is needed in order to identify the most appropriate way to scale literacy test scores in human capital convergence-growth regressions.

Table 5.7

Conditional convergence of GDP per capita, 1960 to 1995

Human capital investment measured by the average test scores of men and women aged 17 to 25, under different scaling methods IFGLS estimations

Dependent variable : Log difference of GDP per capita			
Independent variables	Basic scale	Alternative scale 1	Alternative scale 2
		Men	
Initial GDP	-0.056 ***	-0.064 ***	-0.056 ***
	(0.014)	(0.015)	(0.014)
Literacy	0.067 **	0.007	0.043 **
	(0.030)	(0.005)	(0.019)
	(2.22)	(1.49)	(2.29)
Investment rate	0.035 ***	0.030 ***	0.035 ***
	(0.009)	(0.009)	(0.009)
Fertility rate	-0.017 *	-0.016	-0.017 *
	(0.010)	(0.010)	(0.010)
Openness ratio	0.019 **	0.016 *	0.019 **
	(0.008)	(0.009)	(0.008)
R^2	0.55	0.52	0.55
		Women	
Initial GDP	-0.077 ***	-0.089 ***	-0.078 ***
	(0.013)	(0.014)	(0.013)
Literacy	0.099 ***	0.019 ***	0.060 ***
	(0.030)	(0.004)	(0.017)
	(3.29)	(4.51)	(3.47)
Investment rate	0.038 ***	0.031 ***	0.038 ***
	(0.007)	(0.007)	(0.007)
Fertility rate	-0.015 *	-0.011	-0.015 *
	(0.009)	(0.009)	(0.009)
Openness ratio	0.021 ***	0.026 ***	0.019 ***
	(0.007)	(0.006)	(0.007)
R^2	0.57	0.59	0.57

Notes: There are 95 observations in each regression. White heteroskedasticity standard errors are shown in parentheses below the estimated coefficients. The t-statistic is also reported below the standard error for the literacy variable *: significant at 10% level; ** at 5% level; *** at 1% level.

6. Conclusions

The key contribution of the empirical analysis presented in this paper is the derivation and use of new time series of human capital indicators based on literacy scores for a restricted set of 14 OECD countries over the 1960-1995 period. We first derive synthetic time series on the literacy level of labour market entrants (people aged 17 to 25) from the age structure of the 1994 International Adult Literacy Survey. This information is then used as a measure of investment in education in a panel data analysis of cross-country growth. The key results as well as the limitations of the analysis are presented in the following paragraphs. We finally conclude with a suggestion for further research to improve our understanding of the differential growth effects of direct indicators of human capital versus indicators based on years of schooling.

The central result of the paper is that direct measures of human capital based on literacy scores outperform measures based on years of schooling in growth regressions of a sub-set of OECD countries. Furthermore, it appears that, overall, human capital indicators based on literacy scores have a positive and significant effect on the transitory growth path, and on the long run levels of GDP per capita and labour productivity. The key economic policy implication that comes out of this result is that, in contrast to previous findings - with the notable exception of de la Fuente and Doménech's (2002) - human capital accumulation matters for the long run wellbeing of developed nations.

One limitation of this empirical analysis is that the significance of the point estimate of the literacy scores for the overall population on GDP per capita and productivity is affected by the removal of the United Kingdom from the sample of countries but remains otherwise significant when any other country is removed from the sample. On the other hand, one could argue that this robustness requirement is too restrictive given the limited number of cross-sections in the initial sample (14 countries for GDP and 13 for productivity). Furthermore, countries absent from the sample such as Greece, Portugal and Spain, have experienced an important catch-up toward the current OECD mean during the period under study. Those countries also exhibited the most important cross-sectional variances in de la Fuente and Doménech (2002).

Nevertheless, the robustness test results regarding the literacy of the total population might be an indication of a problem given the fact that only the literacy variable measured from the scores obtained by women exhibits strong robustness in the growth regressions and is almost not affected by the sample adjustment. The fact that literacy indicators for the female population systematically outperform comparable indicators of the male population in growth regressions and produce very robust results is the second highlight of the empirical analysis. As discussed in the paper, we propose five reasons to explain why the literacy investment of female might matter more than their male counterpart in the neo-classical growth framework. One could, however, argue that the relative performance of male and female literacy illustrates that MRW-type growth regressions might not be the appropriate empirical framework to estimate the effect of human capital accumulation on output. Hall and Jones (1999) have argued that here is a specification problem in MRW-type growth regressions because a productivity shock is likely to affect both human capital accumulation and the growth rate of output. It might be impossible to interpret the

results structurally. In our case, female literacy might perform better because it is positively correlated with social infrastructure.

Another way to see the limitation of the empirical analysis is to consider the growth models of open economies with physical capital mobility, such as in Barro, Mankiw, and Sala-i-Martin (1995). In this set-up, the accumulation of physical capital is driven by the accumulation of human capital since the latter cannot be financed in international capital markets. In this case, as discussed in Coulombe (2001), it is not clear what is measured when the growth rate of per capita output is regressed on initial human capital and per capita output. At best, the human capital variable might capture an imbalance effect that occurs when the initial human capital to physical capital ratio is not in equilibrium. At worst, the human capital variable might be correlated with other omitted variables that cannot be adequately measured. That might be the case if female literacy is positively correlated, for example, with the degree of social development in OECD countries. Again in this case, the point estimate of female literacy might capture other things than the direct effect of human capital on productivity.

But we consider that the central result of the paper is not threatened by the limitations of the empirical analysis. Literacy scores data contain more information on the relative wellbeing of nations than the years of schooling data. We therefore propose two plausible explanations for our central result. First, from the perspective of one particular country, literacy scores might be a better measure of an important determinant of growth (such as human capital or social infrastructure) than years of schooling. Second, literacy data might simply be more comparable on a cross-country basis than years of schooling. To provide researchers with international data on skills that are comparable on a cross-country basis is one of the great merits of the International Adult Literacy Survey initiative. But we do not have a data bank for “adjusted years” of schooling that are as comparable at the cross-country level as the literacy scores. More research is needed in order to determine which explanation, or a combination of the two, is to be favoured.

One way to address this potentially important economic policy issue in an empirical analysis would be to compare the growth effects at the provincial level of alternative indicators of human capital based on years of schooling and literacy scores in a country like Canada. As shown in the study of Coulombe and Tremblay (2001), a large number of educational achievement indicators are available across provinces going back to the census of 1951. The idea in this research would be to separate the data comparability problem from the issue related to schooling measures versus literacy indicators, since years of schooling are much more comparable across provinces of a country like Canada than across countries. Such research might prove to be a decisive step for choosing between the two alternative interpretations of our central result. If literacy scores perform better than the years of schooling indicators, one should conclude that the direct approach to the measurement of human capital based on comparable literacy scores has a clear advantage over the years of schooling approach, and that literacy matters more for economic growth than years of schooling.

Appendix A

Table A.1

GDP per capita in purchasing power parities

	1960	1965	1970	1975	1980	1985	1990	1995
Belgium	7,782	9,710	12,226	14,007	15,911	16,391	19,816	21,025
Canada	10,168	12,161	13,804	16,401	19,119	20,670	22,427	22,818
Switzerland	14,029	16,645	19,130	19,477	20,471	21,779	25,133	24,511
Germany			12,360	13,444	15,512	16,669	19,359	21,049
Denmark	10,773	13,571	15,847	16,374	17,645	19,491	21,574	23,532
Finland	7,394	9,207	11,297	13,691	15,075	17,059	20,284	18,852
United Kingdom	9,641	10,851	12,111	12,833	14,377	15,820	18,314	19,544
Ireland	5,212	6,080	7,451	8,554	9,672	11,174	14,562	17,295
Italy	6,808	8,559	11,258	12,215	14,516	15,864	19,316	20,148
Netherlands	9,358	11,007	13,405	15,017	16,142	17,091	19,670	20,966
Norway	8,771	10,644	12,559	14,926	18,706	21,467	21,024	23,413
New Zealand	11,437	13,535	13,311	14,246	13,750	15,300	16,034	17,379
Sweden	10,467	12,956	15,311	16,918	17,145	18,692	20,933	20,811
United States	12,599	14,998	16,831	18,377	21,180	23,593	26,365	28,381

Table A.2

GDP per worker in purchasing power parities

	1960	1965	1970	1975	1980	1985	1990	1995
Belgium	20,256	25,781	32,427	36,272	40,767	41,022	47,664	50,154
Canada	27,874	31,950	34,692	37,032	38,585	41,359	44,744	45,021
Switzerland	32,075	37,577	43,346	42,521	46,121	46,673	49,118	44,289
Germany							39,486	42,529
Denmark	24,068	29,367	33,205	32,852	34,654	37,173	39,147	44,352
Finland	16,391	19,720	23,899	28,545	31,222	34,194	40,950	38,189
United Kingdom	20,919	23,590	26,272	28,053	29,915	32,292	37,091	39,699
Ireland	13,016	15,482	19,079	22,594	26,926	28,738	36,727	44,791
Italy	16,700	21,180	28,883	32,297	39,624	41,227	47,615	50,605
Netherlands	26,043	30,533	36,797	39,531	42,024	41,624	46,712	44,763
Norway	20,991	24,305	27,024	31,109	34,998	39,229	40,129	48,168
New Zealand	30,856	35,402	35,083	37,467	33,820	36,778	35,690	36,956
Sweden	23,242	28,142	31,990	34,119	34,264	36,869	39,975	39,802
United States	30,304	35,363	38,432	39,735	44,217	48,164	53,887	56,065

Figure A.1

Average literacy score of women aged 17 to 25 relative to the cross-section mean

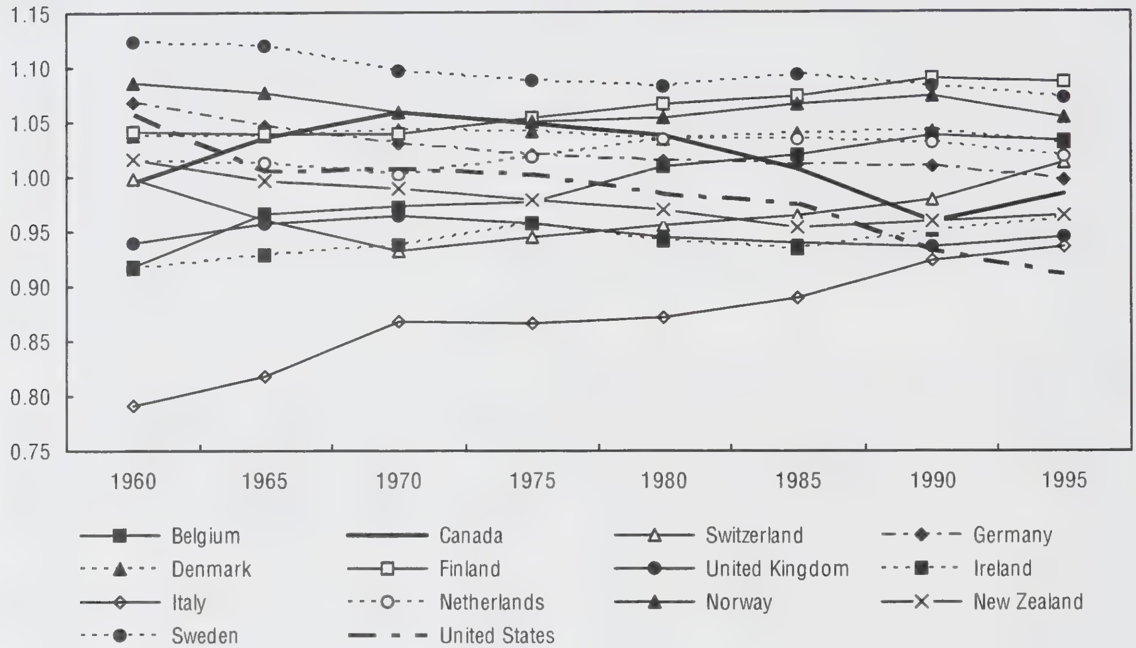


Figure A.2

Average literacy score of men aged 17 to 25 relative to the cross-section mean

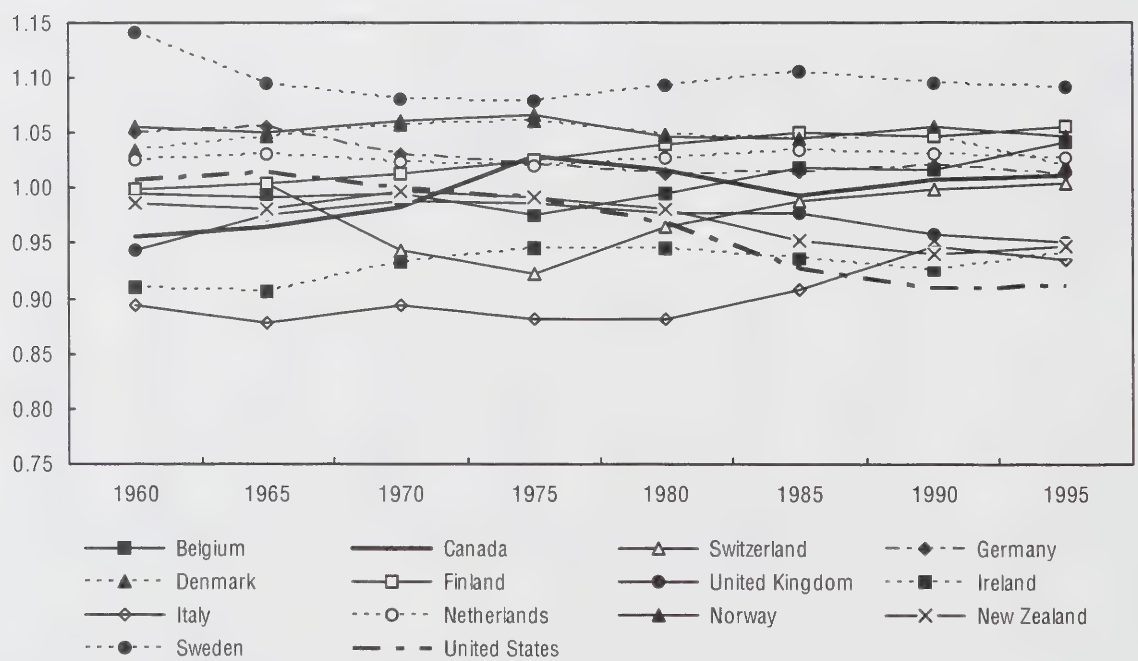


Figure A.3

Percentage of population aged 17 to 25 that achieved at least level 4 (Prose) relative to the cross-section mean

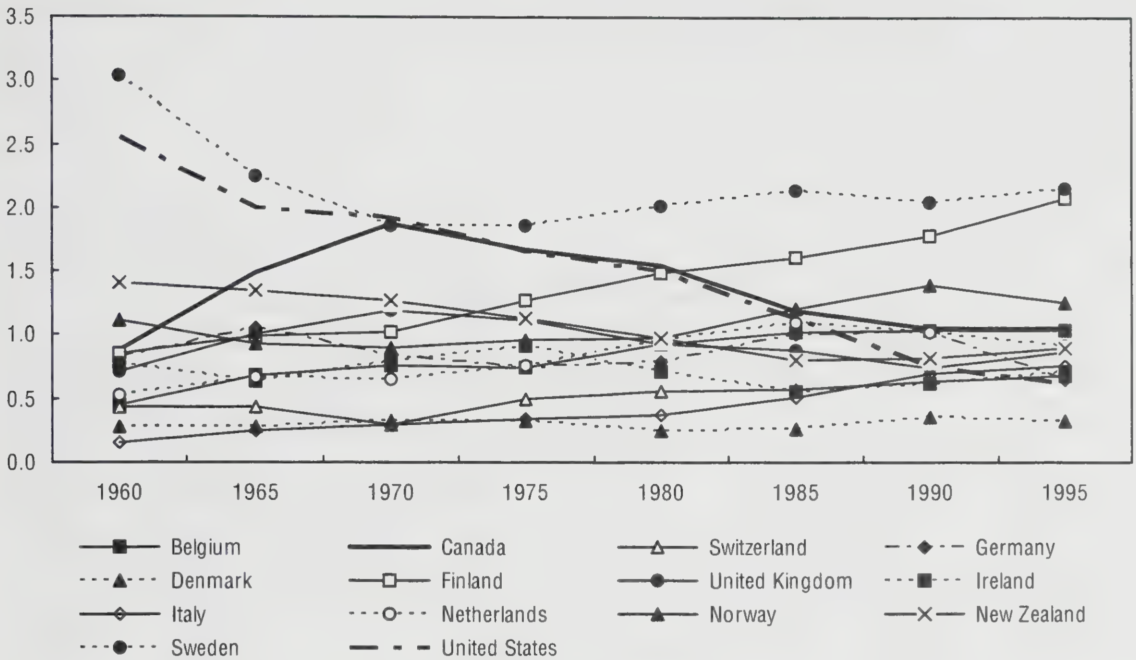


Figure A.4

Percentage of population aged 17 to 25 that achieved at least level 4 (Quantitative) relative to the cross-section mean

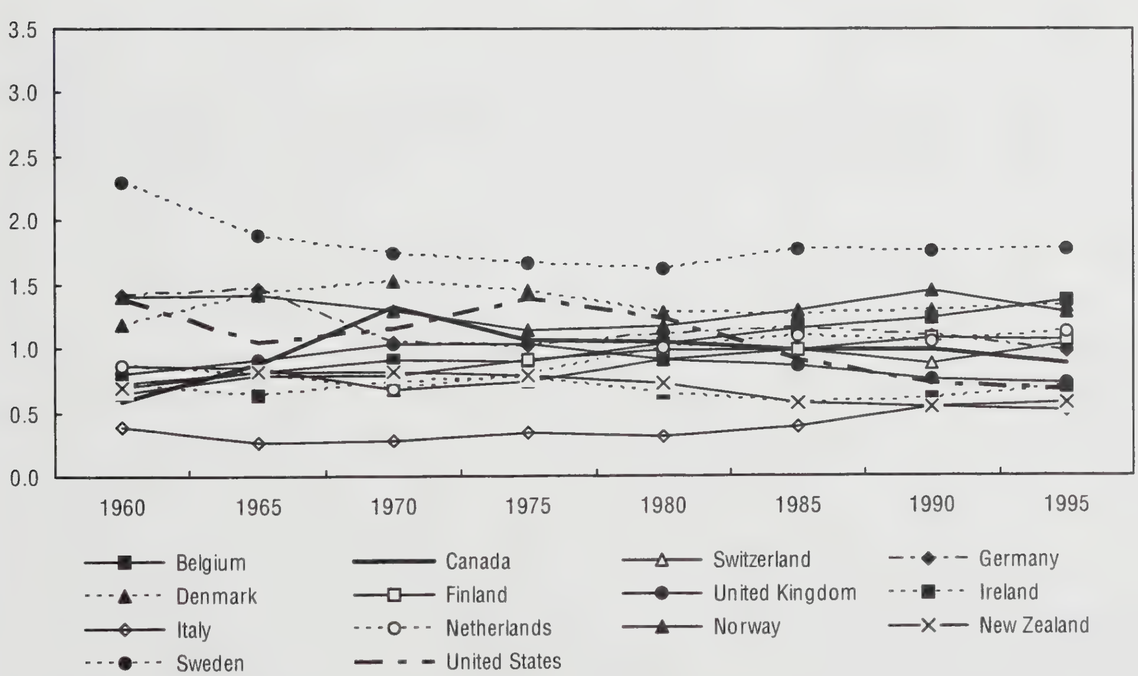
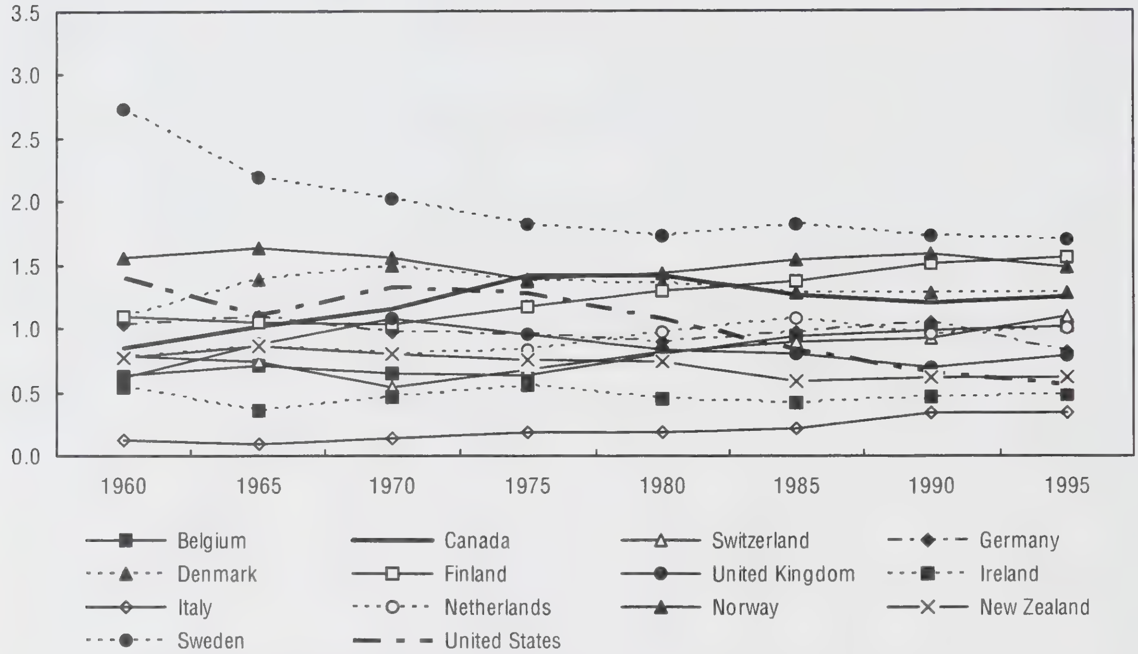


Figure A.5

Percentage of population aged 17 to 25 that achieved at least level 4 (Document) relative to the cross-section mean



Appendix B

Table B.1

Conditional convergence of GDP per capita, 1960 to 1985

Human capital investment measured by average test scores of the population aged 17 to 25
IFGLS estimations with country fixed effects

Dependent variable : Log difference of GDP per capita				
Independent variables	Literacy	Prose	Quantitative	Document
Initial GDP	-0.058 ***	-0.057 ***	-0.059 ***	-0.056 ***
	(0.015)	(0.015)	(0.015)	(0.015)
Literacy	0.104 ***	0.116 ***	0.103 ***	0.085 **
	(0.034)	(0.035)	(0.036)	(0.032)
Investment rate	0.035 ***	0.037 ***	0.033 ***	0.035 ***
	(0.007)	(0.007)	(0.007)	(0.007)
Fertility rate	0.001	-0.003	0.003	0.002
	(0.010)	(0.010)	(0.010)	(0.011)
R^2	0.63	0.65	0.62	0.62
Elasticities (K; H)	(0.60; 1.79)	(0.65; 2.04)	(0.56; 1.75)	(0.63; 1.52)
Implied (α; η)	(0.18; 0.53)	(0.18; 0.55)	(0.17; 0.53)	(0.20; 0.48)

Notes: There are 68 observations in each regression. White heteroskedasticity standard errors are shown in parentheses below the estimated coefficients. *: significant at 10% level; ** at 5% level; *** at 1% level. No significant serial correlation in all regressions.

Table B.2

Conditional convergence of GDP per capita, 1960 to 1995

Human capital investment measured by average test scores of the population aged 17 to 25
IFGLS estimations without country fixed effects

Dependent variable : Log difference of GDP per capita

Independent variables	Literacy	Prose	Quantitative	Document
Initial GDP	-0.034 ***	-0.034 ***	-0.034 ***	-0.034 ***
	(0.005)	(0.005)	(0.005)	(0.005)
Literacy	0.007	0.008	0.008	0.004
	(0.015)	(0.016)	(0.015)	(0.014)
Investment rate	0.023 ***	0.023 ***	0.023 ***	0.023 ***
	(0.006)	(0.006)	(0.006)	(0.006)
Fertility rate	-0.005	-0.005	-0.004	-0.005
	(0.005)	(0.005)	(0.005)	(0.005)
R^2	0.35	0.35	0.35	0.34
Elasticities (K; H)	(0.68; 0.21)	(0.68; 0.24)	(0.68; 0.24)	(0.68; 0.12)
Implied (α; η)	(0.36; 0.11)	(0.35; 0.12)	(0.35; 0.12)	(0.38; 0.07)

Notes: There are 96 observations in each regression. White heteroskedasticity standard errors are shown in parentheses below the estimated coefficients. *: significant at 10% level; ** at 5% level; *** at 1% level. No significant serial correlation in all regressions.

Table B.3

Conditional convergence of GDP per capita, 1960 to 1985

Human capital investment measured by average test scores of the population aged 17 to 25
IFGLS estimations without country fixed effects

Dependent variable : Log difference of GDP per capita

Independent variables	Literacy	Prose	Quantitative	Document
Initial GDP	-0.028 ***	-0.026 ***	-0.030 ***	-0.028 ***
	(0.005)	(0.004)	(0.005)	(0.005)
Literacy	0.042 **	0.051 ***	0.038 **	0.033 **
	(0.017)	(0.016)	(0.019)	(0.016)
Investment rate	0.023 ***	0.023 ***	0.023 ***	0.023 ***
	(0.005)	(0.005)	(0.006)	(0.006)
Fertility rate	0.000	0.001	-0.000	0.000
	(0.006)	(0.006)	(0.006)	(0.006)
R^2	0.48	0.51	0.46	0.46
Elasticities (K; H)	(0.82; 1.50)	(0.88; 1.96)	(0.77; 1.27)	(0.82; 1.18)
Implied (α; η)	(0.25; 0.45)	(0.23; 0.51)	(0.25; 0.42)	(0.27; 0.39)

Notes: There are 68 observations in each regression. White heteroskedasticity standard errors are shown in parentheses below the estimated coefficients. *: significant at 10% level; ** at 5% level; *** at 1% level. No significant serial correlation in all regressions.

Appendix C

Table C.1

Conditional convergence of GDP per capita, 1960 to 1995

Human capital investment measured by the share of men and women aged 17 to 25 that achieved levels 4 or 5

IFGLS estimations

Dependent variable : Log difference of GDP per capita			
Independent variables	Prose	Quantitative	Document
		Men	
Initial GDP	-0.063 *** (0.015)	-0.064 *** (0.015)	-0.063 *** (0.014)
Literacy	0.002 (0.002)	0.003 (0.005)	0.003 (0.004)
Investment rate	0.031 *** (0.009)	0.029 *** (0.009)	0.029 *** (0.008)
Fertility rate	-0.018 * (0.009)	-0.017 * (0.010)	-0.016 (0.010)
Openness ratio	0.014 (0.009)	0.016 * (0.009)	0.015 * (0.009)
R^2	0.51	0.52	0.52
Elasticities (K; H)	(0.49; 0.03)	(0.45; 0.05)	(0.46; 0.05)
		Women	
Initial GDP	-0.066 *** (0.012)	-0.064 *** (0.014)	-0.064 *** (0.013)
Literacy	0.006 *** (0.002)	0.005 * (0.003)	0.005 (0.003)
Investment rate	0.033 *** (0.008)	0.025 *** (0.007)	0.030 *** (0.008)
Fertility rate	-0.016 * (0.009)	-0.013 (0.010)	-0.016 (0.010)
Openness ratio	0.019 *** (0.006)	0.017 ** (0.007)	0.017 ** (0.007)
R^2	0.57	0.54	0.53
Elasticities (K; H)	(0.50; 0.09)	(0.39; 0.08)	(0.47; 0.08)

Notes: There are 95 observations in each regression. White heteroskedasticity standard errors are shown in parentheses below the estimated coefficients. *: significant at 10% level; ** at 5% level; *** at 1% level. No significant serial correlation in all regressions.

Table C.2

Conditional convergence of GDP per capita, 1960 to 1995

Human capital investment measured by the share of men and women aged 17 to 25 that achieved levels 4 or 5

IWTSLS-IV estimations

Dependent variable : Log difference of GDP per capita			
Independent variables	Prose	Quantitative	Document
		Men	
Initial GDP	-0.066 ***	-0.067 ***	-0.066 ***
	(0.012)	(0.012)	(0.012)
Literacy	0.002	0.003	0.002
	(0.002)	(0.005)	(0.003)
Investment rate	0.029 ***	0.026 ***	0.027 ***
	(0.009)	(0.008)	(0.008)
Fertility rate	-0.019 **	-0.019 **	-0.018 *
	(0.009)	(0.009)	(0.009)
Openness ratio	0.018 **	0.020 **	0.018 **
	(0.009)	(0.008)	(0.008)
Elasticities (K; H)	(0.44; 0.03)	(0.39; 0.04)	(0.41; 0.03)
		Women	
Initial GDP	-0.066 ***	-0.063 ***	-0.065 ***
	(0.011)	(0.012)	(0.012)
Literacy	0.006 ***	0.006 **	0.005 *
	(0.002)	(0.003)	(0.003)
Investment rate	0.034 ***	0.024 ***	0.030 ***
	(0.008)	(0.007)	(0.008)
Fertility rate	-0.016 *	-0.013	-0.016 *
	(0.008)	(0.009)	(0.009)
Openness ratio	0.019 **	0.019 **	0.019 **
	(0.008)	(0.008)	(0.008)
Elasticities (K; H)	(0.52; 0.09)	(0.38; 0.10)	(0.46; 0.08)

Notes: There are 94 observations in each regression. White heteroskedasticity standard errors are shown in parentheses below the estimated coefficients. *: significant at 10% level; ** at 5% level; *** at 1% level. Instruments used for the IWTSLS-IV estimations are initial GDP per capita and the lagged values of the investment rate, of the fertility rate and of the de la Fuente and Doménech average schooling years variable. No significant serial correlation in all regressions.

Table C.3

Coefficient on the share of the population aged 17 to 25 that achieved literacy level 1 only in conditional convergence regressions, 1960 to 1995

Dependent variable : Log difference of GDP per capita			
Independent variables	Prose	Quantitative	Document
Population	-0.011 **	-0.007	-0.005
	(0.005)	(0.004)	(0.004)
Men	-0.008 **	-0.007 **	-0.008 ***
	(0.004)	(0.003)	(0.003)
Women	-0.007 *	-0.004	0.001
	(0.004)	(0.003)	(0.004)
Dependent variable : Log difference of GDP per worker			
Population	-0.009 *	-0.007 *	-0.006
	(0.005)	(0.004)	(0.004)
Men	-0.003	-0.006 *	-0.007 **
	(0.005)	(0.003)	(0.003)
Women	-0.009 **	-0.005	-0.001
	(0.004)	(0.003)	(0.004)

Notes: IFGLS estimations. There are 95 observations in each regression. White heteroskedasticity standard errors are shown in parentheses below the estimated coefficients. *: significant at 10% level; ** at 5% level; *** at 1% level.

Appendix D

Table D.1

Conditional convergence of GDP per capita, 1960 to 1995

Human capital investment measured by average literacy scores of men and women aged 17 to 25

Dependent variable: Log difference of GDP per capita

Independent variables	IFGLS Men		IFGLS Women		IWTSLS-IV Men		IWTSLS-IV Women	
Initial GDP	-0.065	***	-0.082	***	-0.065	***	-0.082	***
	(0.014)		(0.013)		(0.012)		(0.012)	
Women labour participation	-0.087	**	-0.093	***	-0.089	***	-0.093	***
	(0.034)		(0.032)		(0.032)		(0.031)	
Literacy	0.047		0.094	***	0.047		0.094	***
	0.029		0.030		0.030		0.029	
Openness ratio	0.013	*	0.012	*	0.013		0.012	
	0.008		0.007		0.008		0.008	
Investment rate	0.031	***	0.038	***	0.030	***	0.038	***
	(0.009)		(0.007)		(0.008)		(0.008)	
Fertility rate	-0.020	**	-0.017	**	-0.019	**	-0.017	**
	(0.009)		(0.008)		(0.008)		(0.008)	
R^2	0.58		0.59					

Notes: There are respectively 94 and 95 observations in each IWTSLS-IV and IFGLS regression. White heteroskedasticity standard errors are shown in parentheses. *: Significant at 10% level; ** at 5% level; *** at 1% level. Instruments used for the IWTSLS-IV estimations are initial GDP per worker and the lagged values of the investment rate, of the openness ratio, of the fertility rate, of the de la Fuente and Doménech average schooling years variable and of the labour force participation of women.

Table D.2

Conditional convergence of GDP per worker, 1960 to 1995

Human capital investment measured by average literacy scores of men and women aged 17 to 25

Dependent variable: Log difference of GDP per worker

	IFGLS		IWTSLS-IV	
Independent variables	Men	Women	Men	Women
Initial GDP	-0.054 ***	-0.070 ***	-0.054 ***	-0.070 ***
	(0.011)	(0.010)	(0.010)	(0.009)
Women labour participation	-0.155 ***	-0.158 ***	-0.156 ***	-0.158 ***
	(0.037)	(0.028)	(0.034)	(0.029)
Literacy	0.056 **	0.105 ***	0.058 **	0.105 ***
	(0.026)	(0.023)	0.026	(0.022)
Openness ratio	0.016 ***	0.017 ***	0.016 ***	0.017 ***
	(0.005)	(0.004)	0.006	0.006
Investment rate	0.028 ***	0.034 ***	0.028 ***	0.034 ***
	(0.006)	(0.005)	(0.007)	(0.006)
Fertility rate	0.001	0.010	0.001	0.010
	(0.007)	(0.007)	(0.007)	(0.006)
R^2	0.73	0.75		

Notes: There are respectively 89 and 90 observations in each IWTSLS-IV and IFGLS regression. The pool of countries excludes Germany. White heteroskedasticity standard errors are shown in parentheses. *: Significant at 10% level; ** at 5% level; *** at 1% level. Instruments used for the IWTSLS-IV estimations are initial GDP per worker and the lagged values of the investment rate, of the openness ratio, of the fertility rate, of the de la Fuente and Doménech average schooling years variable and of the labour force participation of women.

Table D.3

Conditional convergence of GDP per capita and GDP per worker, 1960 to 1995

Human capital investment measured by average literacy scores of the population aged 17 to 25

Dependent variable: Log difference of

	GDP per capita		GDP per worker	
Independent variables	IFGLS	IWTSLS-IV	IFGLS	IWTSLS-IV
Initial GDP	-0.071 ***	-0.070 ***	-0.059 ***	-0.059 ***
	(0.013)	(0.011)	(0.010)	(0.009)
Women labour participation	-0.088 **	-0.089 ***	-0.162 ***	-0.163 ***
	(0.034)	(0.032)	(0.033)	(0.032)
Literacy	0.081 **	0.081 **	0.092 ***	0.093 ***
	(0.034)	(0.033)	(0.027)	(0.028)
Openness ratio	0.014 *	0.013	0.016 ***	0.016 ***
	(0.007)	(0.008)	(0.004)	(0.006)
Investment rate	0.035 ***	0.035 ***	0.032 ***	0.032 ***
	(0.008)	(0.008)	(0.006)	(0.007)
Fertility rate	-0.018 *	-0.017 **	0.005	0.006
	(0.009)	(0.008)	(0.007)	(0.007)
R^2	0.59		0.75	

Notes: There are respectively 94 and 95 observations in each GDP per capita IWTSLS-IV and IFGLS regression. There are respectively 89 and 90 observations in each GDP per worker IWTSLS-IV and IFGLS regression. White heteroskedasticity standard errors are shown in parentheses. *: Significant at 10% level; ** at 5% level; *** at 1% level. The pool of countries excludes Germany in the case of GDP per worker. Instruments used for the IWTSLS-IV estimations are initial GDP per capita or worker and the lagged values of the investment rate, of the fertility rate, of the de la Fuente and Doménech average schooling years variable and of the labour force participation of women.

Appendix E

Robustness Analysis

Our sample of countries includes only 14 of the entire group of 30 OECD member countries. To assess the representativeness and validity of our results, we repeated the estimations including the full set of independent variables – initial GDP per capita or per worker, the investment rate, the openness ratio, the fertility rate, literacy and the female labour participation rate – whilst removing a different country each time. This resulted in a series of 14 regressions each time. Results are presented in Tables E.1 to E.13. The long run elasticity reported are defined as minus the ratio of the coefficient of the relevant variable to the coefficient of initial GDP per capita.

Table E.1

Long run elasticity of GDP per capita with respect to human capital

Human capital investment measured by average literacy scores of the population aged 17 to 25

Dependent variable: Log difference of GDP per capita using IFGLS				
Country removed from regression	Initial GDP per capita	Long run elasticity of GDP per capita to human capital	Initial GDP per worker	Long run elasticity of GDP per worker to human capital
Belgium	-0.062 *** (0.014)	1.515 **	-0.041 *** (0.011)	3.390 ***
Canada	-0.058 *** (0.013)	1.810 ***	-0.053 *** (0.010)	2.736 ***
Switzerland	-0.075 *** (0.013)	1.200 **	-0.054 *** (0.010)	2.333 ***
Denmark	-0.059 *** (0.013)	1.678 ***	-0.045 *** (0.011)	2.733 ***
Finland	-0.063 *** (0.014)	1.476 ***	-0.047 *** (0.011)	2.489 ***
Germany	-0.066 *** (0.013)	1.515 ***		
Ireland	-0.075 *** (0.013)	1.173 **	-0.060 *** (0.010)	1.683 ***
Italy	-0.063 *** (0.014)	1.571 ***	-0.046 *** (0.012)	2.717 ***
Netherlands	-0.062 *** (0.013)	1.710 ***	-0.049 *** (0.010)	2.612 ***
Norway	-0.065 *** (0.013)	1.462 ***	-0.050 *** (0.011)	2.380 ***
New Zealand	-0.069 *** (0.014)	1.348 **	-0.052 *** (0.011)	2.288 ***
Sweden	-0.069 *** (0.013)	1.246 **	-0.056 *** (0.010)	1.607 ***
United Kingdom	-0.045 *** (0.015)	1.444	-0.026 * (0.015)	2.269
United States	-0.068 *** (0.014)	1.500 **	-0.049 *** (0.012)	2.143 ***

Notes: There are 88 observations in each regression of GDP per capita, except for the regression that excludes Germany for which there are 90 observations, and there are 83 observations in each regressions of GDP per worker. White heteroskedasticity standard errors are shown in parentheses. *: Significant at 10% level; ** at 5% level; *** at 1% level. The set of independent variables includes the initial GDP per capita, the investment rate, the openness ratio, the fertility rate and the literacy measure.

Table E.2

Conditional convergence of GDP per capita, 1960 to 1995

Human capital investment measured by average literacy scores of men and women aged 17 to 25

Dependent variable: Log difference of GDP per capita using IFGLS

	Men		Women	
Country removed from regression	Literacy	Women labour participation	Literacy	Women labour participation
Belgium	0.044 (0.030)	-0.093 *** (0.033)	0.095 *** (0.034)	-0.096 *** (0.032)
Canada	0.077 ** (0.033)	-0.040 (0.045)	0.083 ** (0.034)	-0.059 (0.043)
Switzerland	0.032 (0.031)	-0.107 *** (0.031)	0.099 *** (0.031)	-0.107 *** (0.031)
Denmark	0.056* (0.030)	-0.083 ** (0.035)	0.090 *** (0.030)	-0.092 *** (0.033)
Finland	0.047 (0.030)	-0.099 *** (0.032)	0.092 *** (0.028)	-0.101 *** (0.031)
Germany	0.051* (0.030)	-0.066 (-0.046)	0.099 *** (0.030)	-0.066 (0.040)
Ireland	0.038 (0.030)	-0.076 ** (0.035)	0.097 *** (0.030)	-0.082 ** (0.034)
Italy	0.050* (0.030)	-0.086 ** (0.034)	0.095 *** (0.031)	-0.092 *** (0.032)
Netherlands	0.051* (0.029)	-0.103 *** (0.033)	0.098 *** (0.029)	-0.106 *** (0.032)
Norway	0.040 (0.029)	-0.110 *** (0.032)	0.099 *** (0.030)	-0.112 *** (0.031)
New Zealand	0.044 (0.030)	-0.087 ** (0.034)	0.093 *** (0.031)	-0.092 *** (0.033)
Sweden	0.047 (0.030)	-0.076 * (0.040)	0.088 *** (0.030)	-0.087 ** (0.040)
United Kingdom	0.022 (0.033)	-0.061 * (0.034)	0.072 ** (0.035)	-0.070 ** (0.033)
United States	0.053 (0.040)	-0.086 ** (0.035)	0.095 ** (0.037)	-0.095 *** (0.034)

Notes: There are 88 observations in each of the 14 GDP per capita IFGLS regressions, except for the regression that excludes Germany for which there are 90 observations. White heteroskedasticity standard errors are shown in parentheses. *: Significant at 10% level; ** at 5% level; *** at 1% level. The set of independent variables includes initial GDP per capita, the investment rate, the openness ratio, the fertility rate, the literacy measure and women labour force participation.

Table E.3

Conditional convergence of GDP per worker, 1960 to 1995

Human capital investment measured by average literacy scores of men and women aged 17 to 25

Dependent variable: Log difference of GDP per worker using IFGLS	Men		Women	
Country removed from regression	Literacy	Women labour participation	Literacy	Women labour participation
Belgium	0.061 **	-0.157 ***	0.116 ***	-0.151 ***
	(0.027)	(0.038)	(0.024)	(0.028)
Canada	0.125 ***	0.003	0.134 ***	-0.042
	(0.034)	(0.054)	(0.034)	(0.055)
Switzerland	0.055 **	-0.170 ***	0.106 ***	-0.167 ***
	(0.026)	(0.037)	(0.023)	(0.028)
Denmark	0.062 **	-0.152 ***	0.104 ***	-0.157 ***
	(0.026)	(0.038)	(0.024)	(0.028)
Finland	0.063 **	-0.162 ***	0.108 ***	-0.158 ***
	(0.026)	(0.036)	(0.023)	(0.027)
Ireland	0.048 *	-0.147 ***	0.108 ***	-0.152 ***
	(0.027)	(0.038)	(0.023)	(0.028)
Italy	0.054 **	-0.159 ***	0.102 ***	-0.161 ***
	(0.027)	(0.038)	(0.024)	(0.029)
Netherlands	0.060 **	-0.161 ***	0.110 ***	-0.162 ***
	(0.026)	(0.038)	(0.023)	(0.028)
Norway	0.054 **	-0.184 ***	0.104 ***	-0.176 ***
	(0.026)	(0.038)	(0.023)	(0.028)
New Zealand	0.055 **	-0.155 ***	0.102 ***	-0.160 ***
	(0.027)	(0.038)	(0.024)	(0.028)
Sweden	0.056 **	-0.167 ***	0.106 ***	-0.142 ***
	(0.027)	(0.059)	(0.023)	(0.040)
United Kingdom	-0.037	-0.097 **	0.090 ***	-0.138 ***
	(0.043)	(0.040)	(0.032)	(0.031)
United States	0.052 *	-0.154 ***	0.084 ***	-0.168 ***
	(0.028)	(0.039)	(0.027)	(0.032)

Notes: There are 83 observations in each of the 14 GDP per worker IFGLS regressions. White heteroskedasticity standard errors are shown in parentheses. *: Significant at 10% level; ** at 5% level; *** at 1% level. The set of independent variables includes the initial GDP per worker, the investment rate, the openness ratio, the fertility rate, the literacy measure and women labour force participation. Each of the 14 regressions excludes Germany and another specified country from the initial pool of 14.

Table E.4

Long run elasticity of GDP per capita with respect to human capital

Human capital investment measured by average literacy scores of men and women aged 17 to 25

Dependent variable: Log difference of GDP per capita using IFGLS				
	Men		Women	
Country removed from regression	Initial GDP per capita	Long run elasticity of GDP per capita to human capital	Initial GDP per capita	Long run elasticity of GDP per capita to human capital
Belgium	-0.067 *** (0.015)	0.657	-0.079 *** (0.013)	1.203 ***
Canada	-0.052 *** (0.014)	1.481 **	-0.072 *** (0.013)	1.153 **
Switzerland	-0.076 *** (0.014)	0.421	-0.090 *** (0.013)	1.100 ***
Denmark	-0.058 *** (0.014)	0.966 *	-0.076 *** (0.013)	1.184 ***
Finland	-0.061 *** (0.015)	0.770	-0.078 *** (0.013)	1.179 ***
Germany	-0.062 *** (0.014)	0.823 *	-0.081 *** (0.013)	1.222 ***
Ireland	-0.075 *** (0.014)	0.507	-0.089 *** (0.013)	1.090 ***
Italy	-0.066 *** (0.015)	0.758 *	-0.080 *** (0.014)	1.188 ***
Netherlands	-0.062 *** (0.014)	0.823 *	-0.080 *** (0.013)	1.225 ***
Norway	-0.070 *** (0.014)	0.571	-0.087 *** (0.013)	1.138 ***
New Zealand	-0.069 *** (0.015)	0.638	-0.087 *** (0.014)	1.069 ***
Sweden	-0.065 *** (0.014)	0.724	-0.081 *** (0.013)	1.087 ***
United Kingdom	-0.043 *** (0.016)	0.512	-0.060 *** (0.017)	1.200 **
United States	-0.068 *** (0.014)	0.779	-0.087 *** (0.014)	1.092 **
Average of the 14 long run elasticities		0.745 [0.721, 0.769]		1.152 [1.138, 1.166]

Notes: There are 88 observations in each IFGLS regression, except for the regression that excludes Germany for which there are 90 observations. White heteroskedasticity standard errors are shown in parentheses. *: Significant at 10% level; ** at 5% level; *** at 1% level. The set of independent variables includes the initial GDP per capita, the investment rate, the openness ratio, the fertility rate, the literacy measure and women labour force participation. The numbers in square brackets are the 95 per cent confidence interval of the corresponding long run elasticity.

Table E.5

Long run elasticity of GDP per worker with respect to human capital

Human capital investment measured by average literacy scores of men and women aged 17 to 25

Dependent variable: Log difference of GDP per worker using IFGLS

	Men		Women	
Country removed from regression	Initial GDP per worker	Long run elasticity of GDP per worker to human capital	Initial GDP per worker	Long run elasticity of GDP per worker to human capital
Belgium	-0.052 *** (0.013)	1.173 **	-0.065 *** (0.010)	1.785 ***
Canada	-0.040 *** (0.011)	3.125 ***	-0.069 *** (0.011)	1.942 ***
Switzerland	-0.058 *** (0.012)	0.948 **	-0.074 *** (0.010)	1.432 ***
Denmark	-0.051 *** (0.011)	1.216 **	-0.067 *** (0.010)	1.552 ***
Finland	-0.051 *** (0.011)	1.235 **	-0.069 *** (0.010)	1.565 ***
Ireland	-0.061 *** (0.012)	0.787 *	-0.076 *** (0.010)	1.421 ***
Italy	-0.058 *** (0.013)	0.932 **	-0.072 *** (0.011)	1.417 ***
Netherlands	-0.053 *** (0.011)	1.132 **	-0.071 *** (0.010)	1.549 ***
Norway	-0.058 *** (0.012)	0.932 **	-0.073 *** (0.010)	1.425 ***
New Zealand	-0.055 *** (0.012)	1.00 **	-0.071 *** (0.010)	1.437 ***
Sweden	-0.053 *** (0.011)	1.057 **	-0.070 *** (0.010)	1.514 ***
United Kingdom	-0.027 * (0.015)	-1.370	-0.057 *** (0.016)	1.579 ***
United States	-0.055 *** (0.012)	0.945 *	-0.069 *** (0.011)	1.217 ***
Average of the 14 long run elasticities		1.008 [0.943, 1.073]		1.526 [1.503, 1.549]

Notes: There are 83 observations in each IFGLS regression. White heteroskedasticity standard errors are shown in parentheses. *: Significant at 10% level; ** at 5% level; *** at 1% level. The set of independent variables includes the initial GDP per worker, the investment rate, the openness ratio, the fertility rate, the literacy measure and women labour force participation. Each of the 13 regressions excludes Germany and another specified country from the initial pool of 14. The numbers in square brackets are the 95 per cent confidence interval of the corresponding long run elasticity.

Table E.6

Long run elasticity of GDP per capita with respect to women labour participation

Human capital investment measured by average literacy scores of men and women aged 17 to 25

Dependent variable: Log difference of GDP per capita using IFGLS

Country removed from regression	Men: Initial GDP per capita	Men: Long run elasticity of GDP per capita to women labour participation	Women: Initial GDP per capita	Women: Long run elasticity of GDP per capita to women labour participation
Belgium	-0.067 ***	-1.382 **	-0.079 ***	-1.212 **
	(0.015)		(0.013)	
Canada	-0.052 ***	-0.768	-0.072 ***	-0.822
	(0.014)		(0.013)	
Switzerland	-0.076 ***	-1.404 ***	-0.090 ***	-1.190 ***
	(0.014)		(0.013)	
Denmark	-0.058 ***	-1.433 **	-0.076 ***	-1.204 ***
	(0.014)		(0.013)	
Finland	-0.061 ***	-1.623 ***	-0.078 ***	-1.293 ***
	(0.015)		(0.013)	
Germany	-0.062 ***	-1.060	-0.081 ***	-0.815
	(0.014)		(0.013)	
Ireland	-0.075 ***	-1.013 **	-0.089 ***	-0.917 **
	(0.014)		(0.013)	
Italy	-0.066 ***	-1.304 **	-0.080 ***	-1.155 ***
	(0.015)		(0.014)	
Netherlands	-0.062 ***	-1.668 ***	-0.080 ***	-1.330 ***
	(0.014)		(0.013)	
Norway	-0.070 ***	-1.571 ***	-0.087 ***	-1.288 ***
	(0.014)		(0.013)	
New Zealand	-0.069 ***	-1.268 **	-0.087 ***	-1.059 ***
	(0.015)		(0.014)	
Sweden	-0.065 ***	-1.163 *	-0.081 ***	-1.081 **
	(0.014)		(0.013)	
United Kingdom	-0.043 ***	-1.430 *	-0.060 ***	-1.169 **
	(0.016)		(0.017)	
United States	-0.068 ***	-1.258 **	-0.087 ***	-1.090 ***
	(0.014)		(0.014)	
Average of the 14 long run elasticities		-1.310 [-1.273, -1.347]		-1.116 [-1.086, -1.146]

Notes: There are 88 observations in each IFGLS regression, except for the regression that excludes Germany for which there are 90 observations. White heteroskedasticity standard errors are shown in parentheses. *: Significant at 10% level; ** at 5% level; *** at 1% level. The set of independent variables includes the initial GDP per capita, the investment rate, the openness ratio, the fertility rate, the literacy measure and women labour force participation. The numbers in square brackets are the 95 per cent confidence interval of the corresponding long run elasticity.

Table E.7

Long run elasticity of GDP per worker with respect to women labour participation

Human capital investment measured by average literacy scores of men and women aged 17 to 25

Dependent variable: Log difference of GDP per worker using IFGLS				
	Men		Women	
Country removed from regression	Initial GDP per worker	Long run elasticity of GDP per worker to women labour participation	Initial GDP per worker	Long run elasticity of GDP per worker to women labour participation
Belgium	-0.052 *** (0.013)	-3.018 ***	-0.065 *** (0.010)	-2.320 ***
Canada	-0.040 *** (0.011)	0.086	-0.069 *** (0.011)	-0.609
Switzerland	-0.058 *** (0.012)	-2.923 ***	-0.074 *** (0.010)	-2.258 ***
Denmark	-0.051 *** (0.011)	-2.984 ***	-0.067 *** (0.010)	-2.339 ***
Finland	-0.051 *** (0.011)	-3.174 ***	-0.069 *** (0.010)	-2.287 ***
Ireland	-0.061 *** (0.012)	-2.408 ***	-0.076 *** (0.010)	-1.997 ***
Italy	-0.058 *** (0.013)	-2.742 ***	-0.072 *** (0.011)	-2.240 ***
Netherlands	-0.053 *** (0.011)	-3.040 ***	-0.071 *** (0.010)	-2.282 ***
Norway	-0.058 *** (0.012)	-3.167 ***	-0.073 *** (0.010)	-2.407 ***
New Zealand	-0.055 *** (0.012)	-2.816 ***	-0.071 *** (0.010)	-2.254 ***
Sweden	-0.053 *** (0.011)	-3.141 ***	-0.070 *** (0.010)	-2.030 ***
United Kingdom	-0.027 * (0.015)	-3.610 **	-0.057 *** (0.016)	-2.417 ***
United States	-0.055 *** (0.012)	-2.806 ***	-0.069 *** (0.011)	-2.440 ***
Average of the 14 long run elasticities		-2.750 [-2.657, -2.842]		-2.145 [-2.080, -2.209]

Notes: There are 83 observations in each IFGLS regression. White heteroskedasticity standard errors are shown in parentheses. *: Significant at 10% level; ** at 5% level; *** at 1% level. The set of independent variables includes the initial GDP per worker, the investment rate, the openness ratio, the fertility rate, the literacy measure and women labour force participation. Each of the 13 regressions excludes Germany and another specified country from the initial pool of 14. The numbers in square brackets are the 95 per cent confidence interval of the corresponding long run elasticity.

Table E.8

Long run elasticity of GDP per capita with respect to the fertility rate

Human capital investment measured by average literacy scores of men and women aged 17 to 25

Dependent variable: Log difference of GDP per capita using IFGLS

	Men		Women	
Country removed from regression	Initial GDP per capita	Long run elasticity of GDP per capita to the fertility rate	Initial GDP per capita	Long run elasticity of GDP per capita to the fertility rate
Belgium	-0.067 *** (0.015)	-0.296 **	-0.079 *** (0.013)	-0.204 *
Canada	-0.052 *** (0.014)	-0.422 **	-0.072 *** (0.013)	-0.287 **
Switzerland	-0.076 *** (0.014)	-0.288 **	-0.090 *** (0.013)	-0.196 **
Denmark	-0.058 *** (0.014)	-0.350 **	-0.076 *** (0.013)	-0.230 **
Finland	-0.061 *** (0.015)	-0.254	-0.078 *** (0.013)	-0.177
Germany	-0.062 *** (0.014)	-0.309 **	-0.081 *** (0.013)	-0.199 *
Ireland	-0.075 *** (0.014)	-0.177	-0.089 *** (0.013)	-0.122
Italy	-0.066 *** (0.015)	-0.299 **	-0.080 *** (0.014)	-0.201 *
Netherlands	-0.062 *** (0.014)	-0.34 **	-0.080 *** (0.013)	-0.223 **
Norway	-0.070 *** (0.014)	-0.297 **	-0.087 *** (0.013)	-0.198 **
New Zealand	-0.069 *** (0.015)	-0.316 **	-0.087 *** (0.014)	-0.215 **
Sweden	-0.065 *** (0.014)	-0.271	-0.081 *** (0.013)	-0.209
United Kingdom	-0.043 *** (0.016)	-0.279	-0.060 *** (0.017)	-0.186
United States	-0.068 *** (0.014)	-0.418 **	-0.087 *** (0.014)	-0.286 **
Average of the 14 long run elasticities		-0.309 [-0.301, -0.317]		-0.210 [-0.203, -0.216]

Notes: There are 88 observations in each IFGLS regression, except for Germany for which there are 90 observations. White heteroskedasticity standard errors are shown in parentheses. *: Significant at 10% level; ** at 5% level; *** at 1% level. The set of independent variables includes the initial GDP per capita, the investment rate, the openness ratio, the fertility rate, the literacy measure and women labour force participation. The numbers in square brackets are the 95 per cent confidence interval of the corresponding long run elasticity.

Table E.9

Long run elasticity of GDP per worker with respect to the fertility rate

Human capital investment measured by average literacy scores of men and women aged 17 to 25

Dependent variable: Log difference of GDP per worker using IFGLS

	Men		Women	
Country removed from regression	Initial GDP per worker	Long run elasticity of GDP per worker to the fertility rate	Initial GDP per worker	Long run elasticity of GDP per worker to the fertility rate
Belgium	-0.052 *** (0.013)	0.024	-0.065 *** (0.010)	0.174
Canada	-0.040 *** (0.011)	-0.264	-0.069 *** (0.011)	-0.054
Switzerland	-0.058 *** (0.012)	0.013	-0.074 *** (0.010)	0.135
Denmark	-0.051 *** (0.011)	0.006	-0.067 *** (0.010)	0.134
Finland	-0.051 *** (0.011)	0.067	-0.069 *** (0.010)	0.166 *
Ireland	-0.061 *** (0.012)	0.065	-0.076 *** (0.010)	0.181 *
Italy	-0.058 *** (0.013)	0.003	-0.072 *** (0.011)	0.139
Netherlands	-0.053 *** (0.011)	0.030	-0.071 *** (0.010)	0.156
Norway	-0.058 *** (0.012)	-0.005	-0.073 *** (0.010)	0.121
New Zealand	-0.055 *** (0.012)	-0.003	-0.071 *** (0.010)	0.123
Sweden	-0.053 *** (0.011)	-0.027	-0.070 *** (0.010)	0.192
United Kingdom	-0.027 * (0.015)	-0.143	-0.057 *** (0.016)	0.165
United States	-0.055 *** (0.012)	-0.050	-0.069 *** (0.011)	0.064
Average of the 14 long run elasticities		-0.022 [-0.015, -0.029]		0.131 [0.122, 0.139]

Notes: There are 83 observations in each IFGLS regression. White heteroskedasticity standard errors are shown in parentheses. *: Significant at 10% level; ** at 5% level; *** at 1% level. The set of independent variables includes the initial GDP per worker, the investment rate, the openness ratio, the fertility rate, the literacy measure and women labour force participation. Each of the 13 regressions excludes Germany and another specified country from the initial pool of 14. The numbers in square brackets are the 95 per cent confidence interval of the corresponding long run elasticity.

Table E.10

Long run elasticity of GDP per capita with respect to the openness ratio

Human capital investment measured by average literacy scores of men and women aged 17 to 25

Dependent variable: Log difference of GDP per capita using IFGLS				
	Men		Women	
Country removed from regression	Initial GDP per capita	Long run elasticity of GDP per capita to the openness ratio	Initial GDP per capita	Long run elasticity of GDP per capita to the openness ratio
Belgium	-0.067 *** (0.015)	0.175	-0.079 *** (0.013)	0.143
Canada	-0.052 *** (0.014)	0.394 **	-0.072 *** (0.013)	0.255 **
Switzerland	-0.076 *** (0.014)	0.166 *	-0.090 *** (0.013)	0.134 *
Denmark	-0.058 *** (0.014)	0.254 *	-0.076 *** (0.013)	0.170 *
Finland	-0.061 *** (0.015)	0.179	-0.078 *** (0.013)	0.137
Germany	-0.062 *** (0.014)	0.257 *	-0.081 *** (0.013)	0.200 **
Ireland	-0.075 *** (0.014)	0.132	-0.089 *** (0.013)	0.111
Italy	-0.066 *** (0.015)	0.185	-0.080 *** (0.014)	0.147
Netherlands	-0.062 *** (0.014)	0.284 **	-0.080 *** (0.013)	0.201 **
Norway	-0.070 *** (0.014)	0.165	-0.087 *** (0.013)	0.125
New Zealand	-0.069 *** (0.015)	0.182 *	-0.087 *** (0.014)	0.136
Sweden	-0.065 *** (0.014)	0.206 *	-0.081 *** (0.013)	0.157*
United Kingdom	-0.043 *** (0.016)	-0.365	-0.060 *** (0.017)	-0.154
United States	-0.068 *** (0.014)	0.228 *	-0.087 *** (0.014)	0.148
Average of the 14 long run elasticities		0.174 [0.158, 0.191]		0.137 [0.124, 0.149]

Notes: There are 88 observations in each IFGLS regression, except for Germany for which there are 90 observations. White heteroskedasticity standard errors are shown in parentheses. *: Significant at 10% level; ** at 5% level; *** at 1% level. The set of independent variables includes the initial GDP per capita, the investment rate, the openness ratio, the fertility rate, the literacy measure and women labour force participation. The numbers in square brackets are the 95 per cent confidence interval of the corresponding long run elasticity.

Table E.11

Long run elasticity of GDP per worker with respect to the openness ratio

Human capital investment measured by average literacy scores of men and women aged 17 to 25

Dependent variable: Log difference of GDP per worker using IFGLS

Country removed from regression	Men: Initial GDP per worker	Men: Long run elasticity of GDP per worker to the openness ratio	Women: Initial GDP per worker	Women: Long run elasticity of GDP per worker to the openness ratio
Belgium	-0.052 *** (0.013)	0.305 ***	-0.065 *** (0.010)	0.273 ***
Canada	-0.040 *** (0.011)	0.925 ***	-0.069 *** (0.011)	0.497 ***
Switzerland	-0.058 *** (0.012)	0.250 ***	-0.074 *** (0.010)	0.213 ***
Denmark	-0.051 *** (0.011)	0.329 ***	-0.067 *** (0.010)	0.254 ***
Finland	-0.051 *** (0.011)	0.293 ***	-0.069 *** (0.010)	0.238 ***
Ireland	-0.061 *** (0.012)	0.261 ***	-0.076 *** (0.010)	0.214 ***
Italy	-0.058 *** (0.013)	0.266 ***	-0.072 *** (0.011)	0.219 ***
Netherlands	-0.053 *** (0.011)	0.299 ***	-0.071 *** (0.010)	0.234 ***
Norway	-0.058 *** (0.012)	0.225 ***	-0.073 *** (0.010)	0.204 ***
New Zealand	-0.055 *** (0.012)	0.294 ***	-0.071 *** (0.010)	0.230 ***
Sweden	-0.053 *** (0.011)	0.295 ***	-0.070 *** (0.010)	0.253 ***
United Kingdom	-0.027 * (0.015)	-0.769	-0.057 *** (0.016)	0.091
United States	-0.055 *** (0.012)	0.311 ***	-0.069 *** (0.011)	0.232 ***
Average of the 14 long run elasticities		0.253 [0.229, 0.276]		0.242 [0.231, 0.254]

Notes: There are 83 observations in each IFGLS regression. White heteroskedasticity standard errors are shown in parentheses. *: Significant at 10% level; ** at 5% level; *** at 1% level. The set of independent variables includes the initial GDP per worker, the investment rate, the openness ratio, the fertility rate, the literacy measure and women labour force participation. Each of the 13 regressions excludes Germany and another specified country from the initial pool of 14. The numbers in square brackets are the 95 per cent confidence interval of the corresponding long run elasticity.

Table E.12

Long run elasticity of GDP per capita with respect to the investment rate

Human capital investment measured by average literacy scores of men and women aged 17 to 25

Dependent variable: Log difference of GDP per capita using IFGLS

	Men		Women	
Country removed from regression	Initial GDP per capita	Long run elasticity of GDP per capita to the investment rate	Initial GDP per capita	Long run elasticity of GDP per capita to the investment rate
Belgium	-0.067 *** (0.015)	0.453 ***	-0.079 *** (0.013)	0.479 ***
Canada	-0.052 *** (0.014)	0.758 ***	-0.072 *** (0.013)	0.538 ***
Switzerland	-0.076 *** (0.014)	0.350 ***	-0.090 *** (0.013)	0.421 ***
Denmark	-0.058 *** (0.014)	0.547 ***	-0.076 *** (0.013)	0.491 ***
Finland	-0.061 *** (0.015)	0.465 ***	-0.078 *** (0.013)	0.465 ***
Germany	-0.062 *** (0.014)	0.485 ***	-0.081 *** (0.013)	0.459 ***
Ireland	-0.075 *** (0.014)	0.362 ***	-0.089 *** (0.013)	0.418 ***
Italy	-0.066 *** (0.015)	0.481 ***	-0.080 *** (0.014)	0.476 ***
Netherlands	-0.062 *** (0.014)	0.486 ***	-0.080 *** (0.013)	0.474 ***
Norway	-0.070 *** (0.014)	0.413 ***	-0.087 *** (0.013)	0.444 ***
New Zealand	-0.069 *** (0.015)	0.458 ***	-0.087 *** (0.014)	0.446 ***
Sweden	-0.065 *** (0.014)	0.460 ***	-0.081 *** (0.013)	0.454 ***
United Kingdom	-0.043 *** (0.016)	0.978 ***	-0.060 *** (0.017)	0.753 ***
United States	-0.068 *** (0.014)	0.494 ***	-0.087 *** (0.014)	0.446 ***
Average of the 14 long run elasticities		0.514 [0.505, 0.522]		0.483 [0.479, 0.487]

Notes: There are 88 observations in each IFGLS regression, except for Germany for which there are 90 observations. White heteroskedasticity standard errors are shown in parentheses. *: Significant at 10% level; ** at 5% level; *** at 1% level. The set of independent variables includes the initial GDP per capita, the investment rate, the openness ratio, the fertility rate, the literacy measure and women labour force participation. The numbers in square brackets are the 95 per cent confidence interval of the corresponding long run elasticity.

Table E.13

Long run elasticity of GDP per worker with respect to the investment rate

Human capital investment measured by average literacy scores of men and women aged 17 to 25

Dependent variable: Log difference of GDP per worker using IFGLS

	Men		Women	
Country removed from regression	Initial GDP per worker	Long run elasticity of GDP per worker to the investment rate	Initial GDP per worker	Long run elasticity of GDP per worker to the investment rate
Belgium	-0.052 ***	0.544 ***	-0.065 ***	0.538 ***
	(0.013)		(0.010)	
Canada	-0.040 ***	1.137 ***	-0.069 ***	0.601 ***
	(0.011)		(0.011)	
Switzerland	-0.058 ***	0.492 ***	-0.074 ***	0.469 ***
	(0.012)		(0.010)	
Denmark	-0.051 ***	0.566 ***	-0.067 ***	0.514 ***
	(0.011)		(0.010)	
Finland	-0.051 ***	0.547 ***	-0.069 ***	0.497 ***
	(0.011)		(0.010)	
Ireland	-0.061 ***	0.405 ***	-0.076 ***	0.425 ***
	(0.012)		(0.010)	
Italy	-0.058 ***	0.492 ***	-0.072 ***	0.477 ***
	(0.013)		(0.011)	
Netherlands	-0.053 ***	0.558 ***	-0.071 ***	0.503 ***
	(0.011)		(0.010)	
Norway	-0.058 ***	0.515 ***	-0.073 ***	0.492 ***
	(0.012)		(0.010)	
New Zealand	-0.055 ***	0.527 ***	-0.071 ***	0.485 ***
	(0.012)		(0.010)	
Sweden	-0.053 ***	0.535 ***	-0.070 ***	0.451 ***
	(0.011)		(0.010)	
United Kingdom	-0.027 *	1.713 ***	-0.057 ***	0.688 ***
	(0.015)		(0.016)	
United States	-0.055 ***	0.541 ***	-0.069 ***	0.514 ***
	(0.012)		(0.011)	
Average of the 14 long run elasticities		0.659 [0.647, 0.672]		0.512 [0.507, 0.517]

Notes: There are 83 observations in each IFGLS regression. White heteroskedasticity standard errors are shown in parentheses. *: Significant at 10% level; ** at 5% level; *** at 1% level. The set of independent variables includes the initial GDP per worker, the investment rate, the openness ratio, the fertility rate, the literacy measure and women labour force participation. Each of the 13 regressions excludes Germany and another specified country from the initial pool of 14. The numbers in square brackets are the 95 per cent confidence interval of the corresponding long run elasticity.

Appendix F

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Literacy and Numeracy Skill as Indicators of the Quality of Educational Investments

The analyses presented in this report are novel in that they incorporate estimates of the quality of educational investment flows, specifically time series estimates of the literacy and numeracy skill of 17 to 25 year olds approximated from the International Adult Literacy Survey (IALS) database.

Given the centrality of these estimates to the estimation, and the potential import of the findings for public policy, it is important that readers understand how the IALS data were collected, what evidence supports the assumption that the data are comparable across countries, what evidence exists that demonstrates that these skills are important aspects of human capital, and, finally, how the IALS cross-sectional data set was employed to derive a time series of the skill distributions prevailing in previous periods.

How the IALS data were collected

The primary goal of the International Adult Literacy Survey (IALS) was to profile the prose literacy, document literacy and quantitative literacy skills of adults in a range of OECD countries, to explore the determinants of the observed skill levels and to ascertain their relationship to a range of economic and social outcomes. In order to provide valid, reliable and comparable estimates of skill for heterogeneous populations the IALS study relied on a unique blend of educational assessment and household survey methods.

The most novel aspect of the study is that representative samples of adults aged 16 to 65 are asked to take a performance test in their homes. The tests used to assess proficiency are based upon theories that render explicit the factors that underlie the relative difficulty of tasks in each skill domain.

If a significant fraction of the variance in item difficulty is captured in a stable way across heterogeneous populations, one can systematically manipulate the underlying variables – characteristics of the text and the task - to yield an efficient assessment. For the IALS study, a minimum of 90% of the variance in the item difficulty had to be explained across both language and culture to warrant inclusion.

In addition to sampling everyday tasks across an appropriate range of difficulty for intended target populations the assessments also attempted to sample life contexts and common, everyday materials so that no group of individuals was advantaged nor disadvantaged by familiarity. Open–ended free response items are used to increase the authenticity of the assessment.

In order to keep assessment durations within acceptable limits and to provide good coverage of the target cognitive domains a Balanced Incomplete Block (BIB) matrix assessment design was employed.

Sophisticated statistical techniques are used to summarize proficiency from the available cognitive data and to impute scores for respondents for whom insufficient cognitive data is available. These techniques place items and individuals on the same scales, a fact that:

- Provides empirical confirmation of item difficulties predicted by the theory,
- Brings meaning to the scales and to the interpretation of proficiency levels,
- Allows one to explore the relationship of skill to covariates collected on the background questionnaire,
- Yields empirical evidence that items are behaving in psychometrically equivalent ways within and between countries, a prerequisite for comparison, and
- Allows one to compute standard errors that reflect the fact that both the population and cognitive domains have been sampled.

Elaborate procedures were put in place to contain error from other sources such as translation and adaptation of the instruments from source languages, scoring, sampling of individuals and households and administration of the test. Details of the IALS methods, including the policy and scientific rationale for the study, the over-arching framework that guided measurement, assessment frameworks for each domain and the overall design of the study can be obtained from the project website at www.ets.org/all.

What evidence supports the assumption that the data are comparable within and among countries?

Measurement error in studies such as the IALS comes from three sources:

- Error associated with the fact that one has sampled the cognitive domain,
- Error associated with the fact that one has sampled the population,
- Error associated with survey implementation including translation and adaptation of the instruments from source to target languages, deviation from prescribed data collection procedures, editing and coding and scoring.

In order to contain error from these sources to acceptable levels the IALS study incorporated an extensive array of quality assurance procedures, including:

- Explicit detailed standards and guidelines related to all aspects of implementation,
- Mandatory training sessions for key activities that were designed to convey both the practice and theory underlying key design features,
- Extensive vetting and review of national implementation plans, and related corrections before implementation,
- A full pilot survey designed to detect deviation from specified standards and guidelines and empirical tolerances for item performance,
- Explicit quality assurance procedures to be implemented in real time during key phases,
- Post-hoc reporting requirements for key dimensions of quality such as response profiles,
- Post-hoc statistical analysis of achieved quality and coherence, and
- Extensive multi-level, multi-variate analysis to increase the precision of the proficiency estimates and to detect deviation from expected patterns.

Review of the output of these systems suggests several things, including that:

- The outgoing quality of the IALS data is very high – the data are valid, reliable and comparable for the vast majority of countries,
- Of the three sources of error, the error associated with the psychometric dimensions of the study is the smallest, contributing an average of 3-5 points on the 500 point scales,
- Error associated with sampling the population are much larger in magnitude, a fact that reflects the relatively small sample sizes fielded by most countries, contributing an average of roughly 15 points on the 500 point proficiency scales,
- Errors associated with implementation are by far the largest, leading in a few cases to a possibly significant over and under-estimation of mean proficiency in a small number of countries.

Estimates of the magnitude of "potential" bias can be obtained by comparing proficiency estimates for reading literacy for 15 year olds who participated in the OECD PISA study to estimates of prose literacy obtained for youth aged 16 to 25 derived from the IALS study for the same countries. For 21 of 24 countries the estimated mean performance is roughly 4 points higher in IALS, which implies some skill growth after the age of 15. The results for three countries appear to deviate from this pattern. Assuming that PISA is the true value, findings suggest that IALS may overestimate skill levels of 16 to 25 year olds in Germany and Sweden. There may be other explanations for this, however, such as cultural differences in skill development during post-secondary schooling or changes in school quality between the survey dates of IALS and PISA. Another factor may be related to the sample coverage of immigrant minorities and/or their achieved response. Conversely, IALS appears to underestimate proficiency in France, again for reasons that appear to be related to the quality of the sample and/or response patterns. Non-response in France was not corrected for by the adjustment of population weights.

Detailed technical documentation related to IALS can be found in *Adult Literacy in OECD Countries: Technical Report on the First International Adult Literacy Survey,* (NCES, 1998) and in the technical appendices to each of the international comparative reports:

Literacy, Economy and Society: first results of the International Adult Literacy Survey (Statistics Canada and the OECD, 1995)

Literacy Skills for the Knowledge Society: Further results of the International Adult Literacy Survey, (HRDC and OECD, 1997)

Literacy in the Information Age: Final Report of the International Adult Literacy Survey, (Statistics Canada and OECD, 2000)

What evidence exists that demonstrates that these skills are important aspects of human capital

The domains that were assessed in the IALS study were selected, in the first instance, because they satisfied the following five criteria:

- First, cognitive psychology had to identify the skill domains as distinct, non-innate skills that can be learned and taught
- Second, the literature on occupational skill standards, the functioning of labour markets and of social inequality had to identify the skills as socially and economically important
- Third, item response theory had to identify a set of variables that predict relative task difficulty in a stable way in heterogeneous populations
- Fourth, there needed to be a history of measurement that produced valid, reliable and comparable measures in heterogeneous populations

- Finally, there needed to be some basis to assume that the approaches to measurement could be adapted for use within the context of a household survey with a maximum average duration of 90 minutes.

To satisfy the second of these criteria the design team was able to draw on an extensive academic literature. Reviews of US, Australian, UK and Canadian occupational skill standards yielded a common set of skills thought to be essential to job performance (Jones, 1998).

Furthermore, a large microeconomic literature exists that explores the relationship of human capital to individual economic success going back to Adam Smith (Smith, 1789). Since then many theories that can contribute to an explanation of the observed inequality in individual earnings have emerged. Many of them relate to each other and can be used in combination to add explanatory value. A useful starting point is the neoclassical economic framework, in which it is implied that individuals who contribute more to the final value of production should also earn more. Complementing this is the theory of human capital (Shultz, 1961, 1975; Becker, 1962, 1964; Mincer, 1958, 1962, 1974), whose core premise suggests that the relative contribution of individuals depends on the knowledge, skills and other attributes embodied within them (Blaug, 1976).

Labour economists have advanced several competing theories in their efforts to reconcile the available empirical evidence with the initial underlying theory of human capital. For example, the theory of labour-segmented markets, which was popularised by Doeringer and Piore (1971), has traditionally differed from human capital theory in terms of its focus. It has tended to emphasize the characteristics of jobs and job markets, rather than the characteristics of individuals (Duncan & Hoffman, 1979). The theory suggests that different labour markets operate under different circumstances such as regulations, technology, demand and supply, which leads to varying pay and benefits. Many proponents of the theory have suggested that worker productivity and pay are determined more by the job and its technology than by the human capital of the worker (see Velloso, 1995). These conclusions are mostly based on studies that view labour-segmentation as a function of industry. In many such studies, job characteristics are not viewed from the point of view of the individual characteristics (i.e., human capital) needed to carry out occupational tasks.

In contrast, there are other studies (e.g., Osberg, Wolff & Baumol, 1989; Raudenbush and Kasim, 2002) that have considered labour-segmentation as a function of occupation. This approach explicitly makes individual characteristics such as human capital relevant, since they are needed to carry out the tasks of different occupations. Osberg *et al.* (1989) state that because of subcontracting and other developments, industry based classifications of economic activity are becoming increasingly unreliable, and thus there is a need to emphasize the occupational composition of the labour force.

The latter approach to viewing labour-segmentation allows for the possibility to consider whether the returns to qualifications and skills vary by different types of occupations. Indeed, demand side data on occupation skill standards identifies considerable heterogeneity in the skill content of jobs (HRDC, 2003). The Government of Canada's Essential Skills Research Project, which is a large scale effort to profile skill demand by occupation, demonstratres this and confirms the central importance of the relationship between skills and job performance.

Another important theory is signalling theory (Arrow, 1973; Spence, 1973; Stiglitz, 1975; Riley, 1976; Weiss, 1995). Because employers have imperfect information concerning potential employees, such as their ability and future productivity, they face a dilemma when they are hiring. So they have little choice but to infer applicants' abilities to produce by relying on their qualifications that are validated and recognised, such as educational attainment. In short, the theory suggests that education acts as a signalling, or screening device for unobserved characteristics. Even though education is only a proxy for human capital, it is suggested that it is vitally important by serving as a screening or filtering function. Indeed, there are findings (e.g., Black and Lynch, 1996: 266), which suggests that educational credentials are important to employers when hiring, and thus play an important role in providing access to occupations. Signalling will tend to reduce the observed

economic returns to skill to the degree that educational credentials are only partially correlated with true skill.

Much of the foregoing literature suffers from a common weakness - without direct measures of human capital they are constrained by the assumption that those with a specified level of education possess similar knowledge, skills and other attributes. The observed variation in wages within occupations is much larger than can be explained by differences in educational attainment. Such variation is undoubtedly the product of underlying variation in the degree to which firms employ and reward skill and in the actual skill levels of workers.

The design of the IALS study does not offer any insight into inter-firm heterogeneity with respect to skill utilization and reward. But it does provide direct measures that allow for specific skills to be separately valued from the many characteristics that education is supposed to indirectly measure. It also allows for an improved understanding of the correspondence between the inputs and outputs of the human capital formation process. Analysis of the IALS data suggests that educational credentials only account for an average of 60% of the explained variance in skill. This leaves much variance to be explained by other factors. If a particular skill is valued independently from schooling, then schooling may continue to proxy for other characteristics.

In recent years, intense efforts to make direct measures of skills available for research have been made, including the direct measures of literacy proficiency made available through the International Adult Literacy Survey (IALS). Green and Riddell (2001) adjust for literacy proficiency and educational attainment simultaneously using a Mincerian type approach. They find significant returns to literacy proficiency in the Canadian labour market - on the order of 3.0 to 3.5 percent for every 10-point increase in literacy[26]. A more detailed analysis by the same authors (Riddell and Green, 2003) confirms this result and identifies that the return to skills is more or less stable across the entire wage distribution, a fact that suggests that skill is making a direct contribution to productivity rather than being simply an artifact of selection. Riddell and Green also determine that literacy and numeracy skill explain a significant fraction of total wage variation once one has netted out the variation attributable to selection effects that tend to blur the relationship between wages and productive characteristics. This finding implies that the characteristics that remain unmeasured are less important, in relative terms than what has been measured in IALS. While controlling for literacy proficiency, OECD and HRDC (1997) also find that the effect of education on earnings is reduced. Osberg (2000: 8) reports results indicating that 40 to 45 percent of the economic return to education is attributable to literacy proficiency, with the balance attributable to other economically important outcomes of education.

There are numerous other studies using direct assessments of skills. Murnane, Willet and Levy (1995) shows the importance of basic skills has increased between the 70s and mid 80s. In Murnane, Willet, Braatz and Duhaldeborde (2001), three types of skills are examined, namely academic skills, skills at completing elementary tasks quickly, and self-esteem, confirming the importance of basic skills in the US labour market. Riviera-Batiz (1992), using the Young Adult Literacy Survey (YALS) data, shows that quantitative literacy also has an independent effect on earnings over and above the effect of initial education.

Evidence suggests that the returns to literacy skills can substantially vary between countries. For example, Devroye and Freeman (2001) conclude that the U S labour market sorts people by literacy proficiency more than any other country. Blau and Kahn (2001) confirm this by suggesting that knowledge and skills play a significant role in explaining relatively high U.S. wage inequalities. Leuven (2001) also finds that the relation between schooling and cognitive scores is steeper in the U.S. than in other countries. In contrast, Tuijnman (2000) finds that the Polish labour market pays for educational qualifications and for work experience but does not highly reward literacy skills.

Wage returns to literacy skill in Sweden appear to be low in large measure because the quantity and quality of skill is high and inequality is low. As a result Swedish employers are

forced to assign wage differences on other characteristics that contribute to productivity (OECD and HRDC, 1998).

Findings also suggest that returns to skills vary by occupation. Using the National Adult Literacy Survey (NALS) data, Raudenbush and Kasim (2002) borrow Osberg et al.'s (1989) labour-segmented view of an information economy to explore the relationships among social inequalities, inequality in literacy skills and inequality in employment and earnings, both within and between occupational types. They associate "good" occupations with relatively well paying information occupations. In their analysis, the average effect of literacy skills was approximately 25 percent of the contribution of education to earnings. A one standard deviation increase in literacy proficiency was associated with an approximate 18 percent increase in hourly earnings, but this varied by occupational type. For example, they find that in the American labour market the relationship between literacy skills and earnings is steeper in information occupations than non-information occupations. Speciafically, Raudenbush and Kasim (2002) find that wage premia accruing to literacy in the US rises with the information and knowledge intensity of jobs. Finally, Boothby has established that literacy skill attracts significant wage premia in jobs where incumbents are over and under-qualified suggesting that it contributes directly to productivity (Boothby, 2002).

In summary the skills measured in IALS, independently explain a large fraction of wages and other labour market outcomes. The observed influence of skill on labour market outcome is, however, mediated by the relative conditions of supply and demand, with high demand and low and variable supply leading to the largest impacts.

A parallel body of evidence has established the impact that literacy and numeracy skill have on the human capital formation of adults through their participation in post-secondary education and adult education and training. For example, Willms (2003) identifies that literacy and numeracy have a marked effect on post-secondary participation. Tuijnman and Belanger (1997) and Kapsalis (1997) establish very large social inequities in access to adult education and training systems conditional on skill, particularly that offered or supported by employers.

From a macro economic perspective, attempts have been made to augment the early neo-classical growth model of Solow (1956) with a class of endogenous growth models that allow for the effects of the accumulation of human capital (see, for example, Romer, 1986; Lucas,1988; Barro and Sala-I-Martin, 1995; Mankiw, Romer and Weil, 1992). For the most part, such analyses have thus far employed educational attainment on years of schooling as a proxy for human capital.

Although these analyses have confirmed that the impact of human capital on economic growth has been underestimated, the most advanced models fail to yield estimates of the same magnitude as those derived from the microeconomic perspective, a fact that Krueger and Lindahl (2001) attribute to the poor measurement properties of the educational attainment employed in macroeconomic growth models.

This present analysis represents a first attempt at incorporating directly assessed measures of labour quality into endogenous growth models, using the skill of graduating cohorts as a proxy for the quality of the investment flow.

How the IALS cross-sectional data set was employed to derive a time series of the skill distributions prevailing in previous periods

An underlying goal of this analysis is to understand what the relative quality of the investment flow in broadly defined education has been over the past 40 years. The current analysis chooses the average literacy score of the cohort *entering* the labour market (17 to 25) in 1995, 1990, … 1960 as a direct, and hence more informative, proxy of quality.

In the analysis one asks the question "how old was the 17 to 25 year old cohort, for each of the synthetic cohorts, in 1994?"

Youth who were 17 to 25 in 1995 were 16 to 24 in 1994.

Youth who were 17 to 25 in 1990 were 21 to 29 in 1994.

Youth who were 17 to 25 in 1985 were 26 to 34 in 1994.

Youth who were 17 to 25 in 1980 were 31 to 39 in 1994.

Youth who were 17 to 25 in 1975 were 36 to 44 in 1994.

Youth who were 17 to 25 in 1970 were 41 to 49 in 1994.

Youth who were 17 to 25 in 1965 were 46 to 54 in 1994.

Youth who were 17 to 25 in 1960 were 51 to 59 in 1994.

The goal were to derive:

indicators for literacy – prose, document, quantitative – overall and by gender.

the proportions that were level 1, 2, 3, 4 and 5.

The analyses proceeded as follows:

Step 1 organized the data to link with the file of Fuente and Domenech (2001), and creates dummy variables for each of the synthetic cohorts.

Step 2 created the mean literacy scores by individual, for prose, doc, and quant, as well as the five levels.

Step 3 estimated the average scores for each cohort, and saved each set to a temporary file. This was repeated for males and females separately.

Step 4 combined the data for each cohort (combined, males, and females), added the cohort files together, and wrote the data out an excel file.

Papers referring to this work should include the following citation: "Data from the International Adult Literacy Study were used to estimate the average literacy scores of youth aged 17 to 25 for each synthetic cohort. This was done by determining the age of the cohort in 1994, when the IALS data were collected, and estimating the literacy indicators using data for the samples of adults at that age. For example, youth who were 17 to 25 in 1995 were aged 16 to 24 in 1994; youth who were 17 to 25 in 1990 were 21 to 29 in 1994; and so on through to the cohort of youth who were 17 to 25 in 1960, who were 51 to 59 in 1994. This approach assumes that the level of literacy skills measured in 1994 for each cohort is similar to their skills when they were aged 17 to 25; that is, on average, their skills neither increased or decreased as they got older."

The resultant synthetic estimates are available upon request from Statistics Canada at the following email address: scotmur@statcan.ca

Why directly assessed literacy and numeracy skills are better proxies of the quality of investment flows in human capital

The estimates employed in this analysis are more informative because they capture important sources of variance that are not reflected in measures of educational attainment. Specifically, they reflect inter-temporal, inter-individual and inter-regional variance in the quality of early educational experience, the quality of elementary and secondary education and the quality of post-secondary education.

The estimates are, however, less informative than they might otherwise be because they also capture variation attributable to skill gain and loss occurring in adulthood after leaving the initial cycle of education.

Analyses of IALS data suggest that these skill gains are themselves the product of differing patterns of skill use associated with differing work organization and industrial and occupational structure, differing patterns of skill use outside of the job and differing patterns of participation in adult education and training. The same analyses suggest a significant amount of skill loss is occurring, particularly in situations where social and economic demand are weak and incentives for skill use and acquisition are consequently low.

Analysis by Riddell and Green (2003) suggests that literacy and numeracy skill is generated largely from formal education, suggesting that skill gain and loss has a relatively modest impact on skill supply. On the other hand, Desjardins (2004) finds that while schooling has a substantial impact on skills development, learning at work, at home and in the community can also have a substantial impact.

Until data from the Adult Literacy and Life Skills Survey (ALL) becomes available in 2004, it is impossible to estimate the net impact of skill gain and skill loss on the available stock of skill. At this point all we can say is the time series estimates of skill for 17 to 25 year olds will be over-estimated due to post-school skill gain and will be under-estimated due to skill loss. Past skill levels will also be will be slightly overestimated because lower skilled individuals have higher mortality rates (and hence a lower probability of being observed in the current cross-sectional survey). The inclusion of immigrants in the estimates will also tend to over-estimate past skill levels as they are likely to have experienced more rapid skill accumulation than the native born population.

In the interim our assumption is that changes in the quality of education have contributed more to changes in the skill supply than the net effect of skill gain and loss embodied in the current time series estimates.

It must also be acknowledged that the observed economic returns to literacy and numeracy skill might be second order effects i.e. one is really seeing the impact of differences in the mix of technical skills generated by differing post-secondary systems. Research suggests, however, that technical competence depends to a large extent on the mastery of a set of foundation skills, including literacy and numeracy. Thus, literacy and numeracy might best be thought of as necessary but not sufficient condition to achieving higher rates of economic growth documented in this paper.

References

Aghion, P., and Howitt, P. 1997. *Endogenous growth theory*. MIT Press, Cambridge, MA.

Arjona, R., Ladaique, M., and Pearson, M. 2001. Growth, inequality and social protection. Labour Market and Social Policy Occasional Paper 51, OECD, Paris.

Arrow, K. J. 1973. Higher education as a filter. *Journal of Public Economics* 2: 193-216.

Ashenfelter, O., and Krueger, A. 1994. Estimates of the economic return to schooling from a new sample of twins. *American Economic Review* 84(5): 1157-1173.

Barro, R., and Sala-i-Martin, X. 1995. *Economic growth*. McGraw-Hill, New York.

Barro, R. and Sala-i-Martin, X. 1992. Convergence. *Journal of Political Economy* 100: 223-251.

Barro, R., Mankiw, G., and Sala-i-Martin, X. 1995. Capital mobility in neoclassical models of growth. *American Economic Review* 85(1): 103–115.

Barro, R.J. 1991. Economic growth in a cross section of countries. *Quarterly Journal of Economics* 106(2): 407-443.

Barro, R.J. 1997. *Determinants of economic growth: A cross-country empirical study*. MIT Press, Cambridge, MA.

Barro, R.J. 2001. Education and economic growth. In Helliwell, J.F. ed., *The Contribution of Human and Social Capital to Sustained Economic Growth and Well-Being*, OECD, chapter 3, pp. 14-41.

Barro, R.J., and Lee, J.W. 1993. International comparisons of educational attainment. *Journal of Monetary Economics* 32(3): 363-394.

Barro, R.J., and Lee, J.W. 1994. Sources of economic growth. *Carnegie-Rochester Conference Series on Public Policy* (40): 1-46.

Barro, R.J., and Lee, J.W. 1996. International measures of schooling years and schooling quality. *American Economic Review* 86(2): 218–223.

Bassanini, A., and Scarpetta, S. 2001. Does human capital matter for growth in OECD countries? Evidence from pooled mean-group estimates. Economics Department Working Papers No. 282, OECD, January.

Baumol, W.J. 1986. Productivity growth convergence and welfare: What do the long-run data show? *American Economic Review* 76: 1072-85.

Becker, G.S. 1962. Investment in human capital: A theoretical analysis. *Journal of Political Economy* 70(5-2): S9-S49.

Becker, G.S. 1964. *Human capital: a theoretical and empirical analysis with special references to education* (Editions revised in 1975 and 1993). University of Chicago Press, Chicago.

Béjaoui, A. 2000. *L'évolution de la prime associée aux qualifications et son implication quant aux changements de la structures des salaires*. Montréal: Université de Montréal.

Benavot, A. 1989. Education, gender, and economic development: A cross-national study. *Sociology of Education* 62: 14-32.

Berman, E., Bound, J., and Machin, S. 1997. Implications of skilled-biased technological change: International evidence. Working Paper 6166, National Bureau of Economic Research, Cambridge, MA.

Bils, M. and P. Klenow. 2000. Does schooling cause growth? *American Economic Review* 90(5): 1160-1183.

Birdsall, N., Ross D., and Sabot R. 1997. Education growth and inequality. In N. Birdsall and F. Japersen (eds), *Pathways to growth: Comparing East Asia and Latin America*, John Hopkins University Press, Washingtin D.C.

Black, S.E. and Lynch, L.M. 1996. Human capital investments and productivity. *American Economic Review* 86(2): 263-267.

Blau, D.M. 1986. Fertility, child nutrition, and child mortality in Nicaragua: An economic analysis of interrelationships. *The Journal of Developing Areas* 20: 185-202.

Blau, F.D. and Kahn, L.M. 2001. Do cognitive test scores explain higher US wage inequality? Working Paper 8210, National Bureau of Economic Research, Cambridge, MA.

Blaug, M. 1976. The empirical status of human capital theory: A slightly jaundiced survey, *Journal of Economic Literature* 14(3), 827-855.

Boothby, D. 1999. Literacy skills, the knowledge content of occupations and occupational mismatch. Working Paper 99-3E, Applied Research Branch, Human Resource Development Canada, Hull.

Boothby, D. 2002. Literacy skills, occupational assignement and the returns to over- and under-education. Statistics Canada and Human Resources Development Canada, Catalogue no. 89-552-MIE, no. 9.

Boudard, E. 2001. *Literacy proficiency, earnings and recurrent training: A ten country comparatives study*. Stockholm: Institute of International Education.

Bresnahan, T. and Trajtenberg, M. 1995. General purpose technologies: Engines of growth? *Journal of Econometrics* 65: 83-108.

Cain, G.G. and Weininger A. 1973. Economic determinants of fertility: Results from cross-sectional aggregate data. *Demography* 10: 205-223.

Card, D. 1999. The causal effect of education on earnings. In Ashenfelter, O. and Card, D. (eds), *Handbook of Labour Economics*. Elsevier Science, Oxford, pp. 1801-1863.

Carnoy, M. 1995. Education and productivity. in M. Carnoy (ed.), *International Encyclopedia of Economics of Education, Second Edition*. Pergamon Press , Oxford, pp. 125-130.

Caselli, F., Esquivel, G. and Lefort, F. 1996. Reopening the convergence debate: A new look at cross-country growth empirics. *Journal of Economic Growth* 1: 363-389.

Cohen, D. and Soto, M. 2001. Growth and human capital: Good data, good results. CEPR Discussion Paper No. 3025.

Cohn, E. and Addison, J. 1998. The economic returns to lifelong learning in OECD countries. *Education Economics* 6(3): 253-308.

Coulombe, S. 2000. New evidence of convergence across Canadian provinces: The role of urbanization. *Regional Studies* 34(8): 713-725.

Coulombe, S. 2001. The contribution of human capital and urbanization to Canadian regional growth. In J.F. Helliwell, ed., *The contribution of human and social capital to sustained economic growth and well-being*, OECD, chapter 10, pp. 203-220.

Coulombe, S. 2003. Human capital, urbanization and Canadian provincial growth. *Regional Studies* 37(3): 239-250.

Coulombe, S. and Tremblay, J.F. 2001. Human capital and regional convergence in Canada. *Journal of Economic Studies* 28(3): 154-180.

Coulombe, S. and Day, K. 1996. Beta-convergence, sigma-convergence and the stationary-state level of regional disparities: The case of Canada. University of Ottawa Research Paper No. 9608E.

Coulombe, S. and Lee, F.C. 1995. Convergence across Canadian provinces, 1961 to 1991. *Canadian Journal of Economics* 28: 886-898.

De la Fuente, A. and Doménech, R. 2002. Human capital in growth regressions: How much difference does data quality make? An update and further results. Manuscript. Instituto de Análisis Económico (CSIC) and Universidad de Valencia.

De la Fuente, A. 1998. Convergence equations and income dynamics: The source of OECD convergence, 1970-1995. CEPR Discussions Papers 1794.

Destré, G., Lévy-Garboua, L., and Sollogoub, M. 2000. Formation informelle et rendements de l'ancienneté. Communication aux 17iemes Journées de Microéconomie Appliquée Québec.

Devroye, D. and Freeman, R. 2001. Does inequality in skill explain inequality of earnings across advanced countries. Working Paper 8140, National Bureau of Economic Research, Cambridge, Ma.

Doeringer, P. and Piore, M. 1971. *Internal labour markets and manpower analysis*. Lexington Books, Lexington, MA.

Dollar, D., and Gatti, R. 1999. Gender inequality, income, and growth: Are good times good for women ? policy research report on gender and development. Working Paper Series No. 1. The World Bank, Washington D.C.

Duncan, G. J., and Hoffman, S. 1979. On-the-job training and earnings differences by race and sex. *Review of Economics and Statistics* 61(4): 594-603.

Forbes, K.J. 2000. A reassessment of the relationship between inequality and growth. *American Economic Review* 90: 869-887.

Förster, M. 2000. Trends and driving factors in income distribution and poverty in the OECD area. Labour Market and Social Policy Occasional Paper 42, OECD, Paris.

Galor, O., and Weil, D.N. 1996. The gender gap, fertility and growth. *American Economic Review*. 86(3): 374-387.

Gee, J., Hull, G., and Lankshear, C. 1996. *The new work order: Behind the language of new capitalism*. Allan and Unwin , London.

Green, D.A., and Riddle, W.C. 2001. Literacy, numeracy and labour market outcomes in Canada. Statistics Canada and Human Resources Development Canada, No. 89-552-MIE, no 8.

Green, F., Ashton, D., Burchell, B., Felstead, A. and Davies, B. 1998. Are British workers getting more skilled? In A.B. Atkinson and J. Hills (eds) *Exclusion, employment and opportunity*, Centre for the Analysis of Social Exclusion, London School of Economics.

Griliches, Z. 1977. Estimating the returns to schooling: Some econometric problems. *Econometrica* 45: 1-22.

Hall, R. and Jones, C. 1999. Why do some countries produce so much more output per worker than others? *The Quarterly Journal of Economics* 114: 83-116.

Hanushek, E.A. and Kimko, D.D. 2000. Schooling, labor-force quality, and the growth of nations. *American Economic Review* 90(5): 1184-1208.

Hill, M.A. and King, E.M. 1995. Women's education and economic well-being. *Feminist Economics* 1: 21-46.

Holland, C., Cooke, T., and Frank, F. 1998. *Literacy and the new work order: An international literacy review*. The National Organization for Adult Learning, London.

HRDC. 2001. Readers' guide to essential skills profiles. Skills Information Division, Human Resource Development Canada, Hull, Quebec, October 12.

Ishikawa, M. and Ryan, D. 2002. Schooling, basic skills and economic outcomes. *Economics of Education Review* 21: 231-243.

Islam, N. 1995. Growth empirics: A panel data approach. *The Quarterly Journal of Economics* 110(4): 1127-1171.

Islam, N. 1998. Growth empirics: A panel data approach – a reply. *The Quarterly Journal of Economics* 113: 324-329.

Jensen, J. 1998. *Mapping social cohesion: The state of Canadian research*, Ottawa: Canadian Policy Research Networks.

Jones, S. 1999. Skill use and acquisition. In *International life skills survey frameworks: Working drafts*, Background documentation prepared for the meeting of Adult Literacy and Life Skills Survey National Study Managers, September 1999.

Kapsalis, C. 1997. *Employee training: An international perspective*. Statistics Canada and Human Resources Development Canada, No 89-552-MIE, no 2.

Klasen, S. 1999. Does gender inequality reduce growth and development? Evidence from cross-country regressions. Policy Research Report on Gender and Development Working Paper Series, No. 2, The World Bank, Washington D.C.

Klasen, S. 2002. Low schooling for girls, slower growth for all? Cross-country evidence on the effect of gender inequality in education on economic development. *The World Bank Economic Review* 16: 345-376.

Knowles, S., Lorgelly, P.K., and Owen P.D. 2002. Are educational gender gaps a brake on economic development? Some cross-country empirical evidence. *Oxford Economic Papers* 54: 118-149.

Krahn, H.K., and Lowe G.S.1998. *Literacy utilization in Canadian Workplaces*. Statistics Canada and Human Resources Development Canada, No. 89-552-MIE, no. 4.

Lagerloef, N.P. 1999. Gender roles, fertility and growth. Working paper.

Lavoie, M., and Roy, R. 1998. Employment in the knowledge-based economy: A growth accounting exercise for Canada. Research Paper, Applied Research Branch, Human Resources Development Canada, Hull.

Lee, K., Pesaran, M.H., and Smith, R. 1998. Growth empirics: A panel data approach – A comment. *The Quarterly Journal of Economics* 113: 319-323.

Leuven, E. 2000. *Studies in the economics of training*. Universiteit van Amsterdam, Amsterdam.

Leuven, E., Oosterbeek, H. and van Ophem, H. 1999. Explaining international differences in male wage inequality by differences in demand and supply of skill. Working Paper 06-99, SCHOLAR network, Universiteit van Amsterdam, Amsterdam.

Lorgelly, P.K. 2000. Are there gender-separate human capital effects on growth? A review of the recent empirical literature. CREDIT Research Paper No. 00/13, University of Nottingham.

Lorgelly, P.K., and Owen, P.D. 1999. The effect of female and male schooling on economic growth: The Barro-Lee model. *Empirical Economics* 24: 537-557.

Lucas, R.E., 1988. On the mechanics of economic development. *Journal of Monetary Economics* 22(1): 3-42.

Machin, S., Ryan, A., and Van Reenan, J. 1996. Technology and changes in skill structure, evidence from an international panel of industries. Discussion Paper Series, Center for Economic Performance, London School of Economics and Political Science.

Maddison, A. 1982. *Phases of capitalist development*, Oxford University Press, Oxford.

Mankiw, N.G. 1995. The growth of nations. *Brookings Papers on Economic Activity*. I: 275-325.

Mankiw, N.G., Romer, D. and Weil, D.N. 1992. A contribution to the empirics of economic Growth. *Quarterly Journal of Economics* 107(2): 407-437.

Massé, P., Roy, R., and Gingras, Y. .2000. The changing skill structure of employment in Canada, in K. Rubenson and H. G. Schuetze (eds), *Transition to the Knowledge Society: Policies and Strategies for Individual Participation and Learning*. British Columbia Press, Vancouver, BC.

Mauro, L. 2000. Human capital and the regional Italian development: Does unemployment matter? Department of Economics and Statistics, University of Trieste, Working Paper No. 61.

Miller, P., Mulvey, C. and Martin, N. 1995. What do twins reveal about the economic returns to education? A comparison of Australian and U.S. Findings. *American Economic Review* 85(3): 586-599.

Mincer, J. 1958. Investment in human capital and personal income distribution. *Journal of Political Economy* 66(4), 281-302.

Mincer, J. (1962). On-the-job training: Costs, returns, and some implications. *Journal of Political Economy* 70(5-2): 50-79.

Mincer, J. 1974. *Schooling, experience, and earnings*. Columbia University Press, New York.

Mincer, J. 1989. Human capital and the labor market: A review of current research. *Educational Researcher* 18: 27-34.

Murnane, R. J., Willet, J. B., Braatz, M. J., and Duhaldeborde, Y. 2001. Do different dimensions of male high school students' skills predict labour market success a decade later? Evidence from the NLSY. *Economics of Education Review* 20: 311-320.

Murnane, R.J., Willet, J.B. and Levy, F. 1995. The growing importance of cognitive skills in wage determination. *Review of Economics and Statistics* 77(2): 251-266.

Murray, T. S., Kirsch, I. S., and Jenkins, L. B. 1998. *Adult literacy in OECD countries: Technical report on the first International Adult Literacy Survey*. National Centre for Education Statistics, Washington, DC.

OECD and HRDC.1997. *Literacy skills for the knowledge society: further results from the International Adult Literacy Survey*. Paris and Ottawa.

OECD. 1998. *Human Capital Investment: An international comparison*. Paris: Centre for Educational Research and Innovation.

OECD. 2001. *Education policy Analysis*. Paris.

OECD 2002. *Measuring the information economy*. Paris.

OECD and Statistics Canada. 2000. *Literacy in the information age: Final report of the International Adult Literacy Survey*. Paris and Ottawa.

Osberg, L. 1989. Paying information workers. In Osberg, L., Wolff, E.N., and Baumol, W.J. 1989, pp. 47-86.

Osberg, L. 2000. *Schooling, literacy and individual earnings*. Ottawa and Hull: Statistics Canada and Human Resource Development Canada.

Osberg, L., Wolff, E.N., and Baumol, W.J. (1989). *The information economy: The implications of unbalanced growth*. Institute for Research on Public Policy, Halifax.

Osterman, P. 1995. Skill, training, and work organization in American establishments. *Industrial Relations* 34(2): 125-146.

Perotti, R. 1996. Growth, income distribution and democracy: What the data say. *Journal of Economic Growth* 1: 149-187.

Psacharopolous, G. 1985. Returns to education: A further international update and implications. *Journal of Human Resources* 20: 583-604.

Psacharopoulos, G. 1994. Returns to investment in education: a global update. *World Development* 22: 1325-1343.

Raudenbush, S.W., and Kasim, R. M. 1998. Cognitive skill and economic inequality: Findings from the national adult literacy survey. *Harvard Educational Review* 68(1): 33-79.

Raudenbush, S.W., and Kasim, R.M. 2002. *Adult literacy, social inequality, and the information economy: Findings from the National Adult Literacy Survey*. Ottawa and Hull: Statistics Canada and Human Resource Development Canada.

Reder, S. 1994. Practice-engagement theory: A sociocultural approach to literacy across languages and cultures. n B. M. Ferdman, Weber, R.M., and Ramirez, A.G. (eds), *Literacy across languages and culture*. State University of New York Press, New York, pp. 33-74.

Riley, J.G. 1976. Information, screening and human capital. *American Economic Review* 66(2): 254-260.

Ritzen, J., Easterly, W., and Woolcock, M. 2000. On good politicians and bad policy: Social cohesion, institutions, and growth. Policy Research Working Paper 2448, World Bank, Washington, DC.

Rivera-Batiz, F.L. 1992. Quantitative literacy and the likelihood of employment among young adults in the United States. *Journal of Human Resources* 27: 313-328.

Romer, P.M. 1986. Increasing returns and long-run growth. *Journal of Political Economy* 94(5): 1002-1037.

Romer, P.M. 1989. Capital accumulation in the theory of long-run growth. In *Modern business cycle theory*, Barro, R.J. ed., Harvard University Press.

Rychen D.S. and Salganik L.H. (eds) 2001. *Theoretical and conceptual foundations*. Göttingen: Hogrefe and Huber.

Sala-i-Martin X. 2002. 15 years of new growth economics: What have we learnt? Columbia University Working Paper 0102-47.

Schultz, T.W. 1961. Investment in human capital. *American Economic Review*. 51(1): 1-17.

Schultz, T.W. 1975. The value of the ability to deal with disequilibria. *Journal of Economic Literature*. 13(3): 827-846.

Schultz, T.P. 1995. Investment in schooling and health of women and men: Quantities and returns. In T.P. Schultz (ed.), *Investment in women' human capital*, University of Chicago Press, Chicago, Il.

Smith C. 1996. Difference in adults' reading practices and literacy proficiencies. *Reading Research Quarterly* 31(2): 196-219.

Solow, R.M. 1956. A contribution to the theory of economic growth. *Quarterly Journal of Economics* 70(1): 65-94.

Spence, A.M. 1973. Job market signaling. *Quarterly Journal of Economics* 87(3): 355-374.

Stern, D., and Tuijnman, A. C. 1997. Adult basic skills: Policy issues and a research agenda. In Tuijnman, A.C., Kirsch, I.S., and Wagner, D.A. (eds), *Adult basic skills: innovations in measurement and policy analysis*. Hampton Press, New Jersey, pp. 1-16.

Stigler, G. 1961. The economics of information. *Journal of Political Economy* 69: 213-225.

Stokey, N. 1994. Comments on Barro and Lee. *Carnegie-Rochester Conference Series on Public Policy* 40: 47-57.

Summers, R., and Heston, A. 1988. A new set of international comparisons of real product and price levels estimates for 130 countries, 1950-85. *Review of Income and Wealth* 34: 1-26.

Temple, J. 1999. The new growth evidence. *Journal of Economic Literature* 37: 112-156.

Temple, J. 2000. Growth effects of education and social capital in the OECD countries, Economics Department Working Papers No. 263, OECD, October.

Tuijnman, A.T. 2000. Education, literacy and wages in Poland in comparative perspective. Yellow Paper Series, Institute of International Education, Stockholm.

Velloso, J. 1995. Income distribution and education. In Carnoy, M. (ed.), *International encyclopedia of economics of education, Second Edition.* Pergamon Press, Oxford, pp. 230-234.

Weiss, A. 1995. Human capital vs. signalling explanations of wages. *Journal of Economic Perspectives* 9(4) 133-154.

Willms, D.J. and Flanagan, P. 2003. Ready or not? Literacy skills and post-secondary education. Montreal, Canadian Millennium Scholarship Foundation.

Wolff. E.N., and Baumol, W.J., 1989. Sources of postwar growth of information activity in the United States. In Osberg, Wolff, and Baumol 1989, pp. 17-46.

Endnotes

1. Based on the number of papers published in economic reviews and on changes made in last years on macroeconomic and development advanced and intermediate textbooks. For a recent very broad survey on the study of growth economics, refer to Sala-i-Martin (2002).
2. This is the crucial assumption that allows cross-country OLS estimation without the need for instrumental variables (Islam, 1995; Temple, 1999)
3. Of a group of similar countries for which only differences in the variables are allowed.
4. Islam (1995), p. 1153.
5. Temple (1999), p. 126-127.
6. Years of attainment for the population aged 25 and over at the secondary and higher levels.
7. The instruments included the five-year earlier values of log(GDP), the actual values of the schooling, life-expectancy, rule-of-law, and terms-of-trade variables and three area dummy variables for Sub Saharan Africa, Latin America and East Asia. Additional instruments are earlier values of the other variables except the inflation rate. For example, the 1965-75 equation uses the averages of the fertility rate and the government spending ratio for 1960-64. The instrument list also includes the cross product of the lagged value of log(GDP) (in terms of deviation from the mean) with the male schooling variable (in terms of deviation from the mean).
8. Four tests were from the International Association for the Evaluation of Educational Achievement (IEA) and two were from the International Assessment of Educational Progress (IAEP).
9. They specifically state that this is a causal and unidirectional process.
10. Urbanization in this context is considered as a reasonable proxy for economic development.
11. Urban population is defined as " the population living within census metropolitan areas and census agglomeration with over 10,000 inhabitants"
12. A constraint is imposed so that estimated coefficients be the same across the two time periods.
13. Both male and female education variables are simultaneously included on the right hand side of the regression equation in Barro and Lee (1994)
14. Older individuals were tested in some countries.
15. Doug Willms from the University of New Brunswick constructed the data. Appendix F provides readers with an overview of the IALS study, how the synthetic estimates were derived, what is known about the skills relationship to economic growth and their suitability for the present use.
16. These countries are Belgium (Flanders), Canada, Denmark, Finland, Germany, Ireland, Italy, Netherlands, Norway, New Zealand, Sweden, Switzerland, United Kingdom and the United States.
17. The coefficient of correlation, over the 1960-1995 period, between our measure of human capital based on the average literacy score and the average years of schooling variable from de la Fuente and Doménech (2002), all expressed as deviations from the cross-section mean, is equal to 0.38.
18. Appendix A includes additional figures which present the average literacy scores of women and men as well as the percentage of the population that achieved at least level 4 for each of the prose, quantitative and document tests.
19. GDP per worker and labour productivity are considered equivalent expressions in the remaining of the text.
20. In the setup of equation 1 with 5 year time periods, the annual convergence speed is $-\log(1+5\varphi_1)/5$.

21. Cross-country growth regressions often include other explanatory variables such government consumption as a share of GDP, rule-of-law indices, the inflation rate, among others. However, the inclusion of such variables is more relevant for regressions performed over large sets of heterogenous countries than for the relatively similar OECD economies. In fact, these aforementioned variables are not found to have a significant effect on OECD growth in Barro (2001).
22. Comparable data are available for Portugal and will be included in future analyses.
23. An effort will also be made to estimate literacy profiles net of the ex-GDR so that Germany data can be included in the full analysis.
24. De la Fuente and Doménech (2002) conduct a similar robustness analysis (As illustrated in Figure 9 on page 30 of the August 2002 version of their paper.). Their results indicates that, when dropping one country at the time for each of the 21 countries from the regression, the estimated coefficients on human capital, and the associated confidence interval, vary the most when the sample excludes precisely one country among Greece, Portugal and Spain. In fact, their coefficient on human capital is only marginally significant when the sample excludes Portugal.
25. Note that in cases where employment growth is concentrated in knowledge and information intense jobs this effect would increase the relative importance of female skill levels on growth.
26. These returns are for weekly log earnings.

International Adult Literacy Survey

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The International Adult Literacy Survey (IALS) was a seven-country initiative conducted in the fall of 1994. Its goal was to create comparable literacy profiles across national, linguistic and cultural boundaries. Successive waves of the survey now encompass close to 30 countries around the world.

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